HOW DO PEOPLE BUY FUEL-EFFICIENT CARS?

Thesis

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Summary

The purchase of fuel-efficient new vehicles is a decisive factor with regard to reducing energy consumption and CO_2 emissions from road transport. Models forecasting car choice and analyzing the effects of measures to change car choice behavior have focused primarily on sociodemographic differentiation among car buyers, if anything. A substantive amount of models include technical vehicle parameters as sole predictors. Psychological variables such as beliefs, attitudes, or norms related to fuel-efficient cars, as well as symbolic motives (motives to express one's self and one's social position by means of one's car) are rarely included. However, it is important to consider these factors when developing and evaluating effective measures to promote fuel-efficient vehicles.

The aim of this thesis was to gain insight into the psychological factors underlying vehicle purchase with regard to fuel consumption and CO_2 emissions. On the one hand, the results help to improve models to explain and forecast car choice with respect to fuel consumption and CO_2 emissions. These models are imperative for the evaluation of fiscal measures to promote the purchase of fuel-efficient vehicles. On the other hand, the results deliver recommendations for the effective design and implementation of a broad range of measures (e.g., information campaigns).

The data for the different studies of this thesis were mainly provided through a paper-and-pencil survey which was sent in two waves (2005 and 2006) to randomly chosen households within the German- and French-speaking parts of Switzerland.

The main goal of the first study was to explore the complexity of the vehicle market, consumer heterogeneity and the possible consequences of fiscal measures used to promote the purchase of fuel-efficient vehicles. This was done for the case of feebate systems which combine fees for the purchase of highly fuel-inefficient vehicles with rebates for very efficient ones. We distinguish between absolute feebates based strictly on energy consumption of a vehicle and relative feebates normalizing energy consumption by vehicle utility which is to be defined. Examples of surrogates for this utility include car length, floor space, curb weight, number of seats or trunk space.

We analyzed whether absolute or relative feebates encourage more consumers to change to vehicles with lower fuel consumption. For the case of relative feebate systems, counteracting side effects are possible, as vehicle

changes are encouraged that increase relative energy efficiency but not necessarily absolute energy efficiency, which in fact can be adversely affected. Thus, the second research question pertained to the possible degree of such unintended side-effects.

In order to answer these questions, all car models on sale at the end of 2005 were analyzed with regard to possible changes encouraged by an absolute vs. relative design of a feebate scheme and their individual resulting effect on CO_2 emissions. From the conducted survey, we used data of 326 potential new car buyers to study their willingness to change car choice behavior due to rebates.

The survey results suggest that consumers show some, albeit limited, willingness to change behavior to obtain an incentive. However, the analysis of the vehicle market in combination with the survey results shows that measures such as feebates bring about the dilemma of how to simultaneously address more consumers while limiting counteracting effects. This dilemma is rooted in the complexity of the vehicle market and the heterogeneity of consumer groups. In order to find an optimal design of such measures, car choice models to evaluate these measures need to include a highly detailed car fleet and consumer segments differentiated according to relevant psychological factors.

A second study was conducted to identify the relevant psychological variables explaining CO_2 emissions of purchased vehicles. Moreover, this study explored which characteristics the respondents associate with more fuel economical, i.e., fuel-efficient vehicles and how they evaluate these characteristics. Drawing from psychological research on environmental behavior, we studied a model of psychological factors which integrates the theory of planned behavior (TPB) and the norm-activation model (NAM). Symbolic motives were included as an additional factor of influence. This model was tested with survey data from 302 Swiss respondents who reported purchasing a new car for their household since 2002.

The results indicate that CO_2 emissions of the respondents' vehicles depend directly (1) on the valence of less vehicle power and smaller size, which the respondents commonly associated with more fuel economical vehicles, (2) on their personal norm to buy a more fuel economical vehicle, and (3) on their respective perceived behavioral control. Important preconditions for these predictors, in turn, are (1) the awareness of problems such as climate change or dependence on fossil energy sources, and (2) perceived response efficacy of one's own behavior to do something about these problems.

In contrast, symbolic motives inhibit the activation of the personal norm and influence the valence of less power and size negatively.

A third study was aimed to provide theoretical insights into the nature of these psychological constructs by investigating reasons for the gap between intention and revealed behavior. Precisely, we compared determinants of stated importance of fuel consumption with determinants of actual behavior. Survey data was used from (1) potential new car buyers (N_1 = 265) and (2) owners of recently purchased new vehicles (N_2 = 302). Further, it was intended to illustrate consequences of possible proxies of CO_2 impact of a behavior which account for resources and needs due to the individual living situation. By this, we aimed to provide hints for the choice and design of a meaningful proxy. Therefore, for behavior, four proxies were applied which account for resources and needs indicated by household type and socio-economic status in a different way. Last but not least, we strived for practical implications with regard to a more effective promotion of fuel-efficient vehicles.

The results indicate that intention to consider fuel consumption (operationalized by stated importance of fuel consumption) is expressed mainly according to an inner feeling of obligation. Symbolic motives have an inhibiting effect. No significant effects could be observed for perceived behavioral control and valence of less vehicle power and size, which significantly influenced CO_2 emissions of actually purchased vehicles in the second study. The differences between factors explaining this intentional variable vs. factors explaining actual car purchase are assumed to be founded mainly in the nature of the various factors, i.e., in their procedural closeness to behavior.

Comparisons of different proxies of CO_2 impact of a person's car purchase behavior show that results differ considerably with the choice of a proxy. This is important for the evaluation of measures that aim to change behavior which address various groups that differ considerably in their needs and available relevant resources. Generally, a behavioral proxy should be chosen carefully and with regard to the specific characteristics of the respective behavior. A proxy which adjusts CO_2 emissions for household type while also considering other vehicles in the household seems to meet differences in car purchase behavior due to consumers' living situation better than proxies which (a) evaluate CO_2 impact of a person's purchase behavior absolutely, (b) were designed to adjust for socio-economic status of a person's household or (c) consider only the most recently purchased vehicle.

Policy measures to promote the purchase of fuel-efficient vehicles would gain in effect if they consider the psychological factors proven as relevant in the second and the third study. Thus, the development and activation of a personal norm to buy a more fuel economical vehicle should be supported by ensuring that consumers are aware of the problems related to fuel consumption. Consumers have to link their own purchase decision to these problems, i.e., they need to be aware of their respective behavioral options to do something about these problems (response efficacy). This indicates the need for informational components of measures. Furthermore, it is important to strengthen the social context to support the intention to consider fuel consumption within vehicle purchase (social norm). For example, financial incentives could emphasize the social desirability of purchasing fuel-efficient vehicles. Moreover, it is important that people perceive the purchase of fuel-efficient cars by respected persons or institutions (i.e., by models). Here, the public sector can take a leading role and make fuel efficiency a prominent selection criteria for its car fleets. Considering the influence of symbolic motives, it is important to accelerate the shift of symbolic values from traditional characteristics such as car size and power to fuel efficiency. For this aim, fuel efficiency should be actively promoted as a popular feature which is compatible with the needs of consumers regarding other vehicle characteristics. Furthermore, fuel efficiency can gain in popularity by linking it to vehicles with intelligent technology, be it with the intelligent usage of optimized conventional technology or with new alternative technology.

However, in order to ensure the actual translation of the intention to purchase a fuel-efficient vehicle into action, it is decisive to strengthen consumers' perceived behavioral control to purchase a fuel-efficient vehicle as well as a positive attitude towards such vehicles. For this aim, it is recommended to better inform people that such vehicles do not necessarily need to be smaller or that even the vehicles with the smallest engines today have (more than) sufficient power to safely overtake other vehicles when necessary or to climb the typical uphill slopes. Moreover, information and prompts such as fuel efficiency labels should help consumers to better identify fuel-efficient vehicles. In general, various measures affecting different relevant factors and supporting each other should be combined (e.g., fiscal measures accompanied by informational campaigns, labeling of fuel-efficient vehicles and consequent implementation of model behavior by the public sector).

Zusammenfassung

Der Kauf treibstoffeffizienter Neuwagen ist eine der wirkungsvollsten Einflussmöglichkeiten, um den Energieverbrauch und die CO_2-Emissionen des Strassenverkehrs zu reduzieren. Modelle zur Vorhersage des Autokaufes und zur Bewertung möglicher Massnahmen zur Beeinflussung der Konsumenten unterscheiden die Käufer vor allem nach soziodemographischen Merkmalen, wenn überhaupt. Ein beträchtlicher Anteil von Modellen beschränkt sich auf technische Autoparameter als Prädiktoren. Psychologische Variablen, wie zum Beispiel spezifische Überzeugungen, Einstellungen und Normen oder auch symbolische Motive (d.h. Motive, mit dem eigenen Auto die eigene Persönlichkeit oder soziale Position auszudrücken) werden selten betrachtet. Ein Einbezug dieser Faktoren ist jedoch wesentlich für die Entwicklung und Bewertung effektiver Massnahmen, welche effizientere Autos fördern sollen.

Das Ziel dieser Dissertation war es, Erkenntnisse über die psychologischen Faktoren zu gewinnen, welche dem Autokauf in Hinblick auf Treibstoffverbrauch und CO_2-Emissionen zugrunde liegen. Die Ergebnisse tragen einerseits dazu bei, Modelle zu verbessern, welche Treibstoffverbrauch und CO_2-Emissionen eines gewählten Autos erklären und vorhersagen. Solche Modelle sind wichtig, um fiskalische Massnahmen zu bewerten, welche den Kauf effizienter Autos fördern sollen. Auf der anderen Seite liefern die Resultate Empfehlungen für die Entwicklung und effektive Umsetzung einer breiten Spanne von Massnahmen zur Förderung effizienter Autos (z.B. Informationskampagnen).

Die Daten für die verschiedenen Studien dieser Dissertation lieferte hauptsächlich eine schriftliche Befragung, welche in zwei Befragungswellen (2005 und 2006) postalisch an zufällig ausgewählte Haushalte in der deutsch- und französischsprachigen Schweiz verschickt wurde.

Hauptziel der ersten Studie war es, die Komplexität des Automarktes, die Heterogenität der Konsumenten und Konsequenzen für fiskalische Massnahmen zur Förderung treibstoffeffizienter Autos zu untersuchen. Dies erfolgte am Beispiel von Bonus-Malus-Systemen, welche Abgaben für den Kauf sehr ineffizienter Autos mit Rabatten für den Kauf sehr effizienter Autos kombinieren. Wir unterscheiden zwischen absoluten Systemen, welchen der absolute Treibstoffverbrauch eines Autos zugrunde liegt, und relativen Systemen, welche den Treibstoffverbrauch mittels eines zu definierenden Autonutzens

normieren. Stellvertretende Variablen für diesen Nutzen können z.B. Autolänge, Grundfläche, Leergewicht, Anzahl Sitzplätze oder das Kofferraumvolumen sein.

Konkret wurde die Frage untersucht, ob Bonus-Malus-Systeme mit absoluter oder relativer Bezugsbasis mehr Konsumenten ansprechen und eine Änderung ihres Kaufverhaltens bewirken können. Im Fall von relativen Bonus-Malus-Systemen sind Effekte möglich, welche dem Ziel der Massnahme entgegenwirken. Solche Systeme fördern einen Wechsel zu Autos mit besserer relativer Energieeffizienz, was aber nicht unbedingt eine bessere absolute Energieeffizienz bedeutet. Letztere kann tatsächlich entgegengesetzt beeinflusst werden. Somit betraf die zweite Forschungsfrage das mögliche Ausmass solcher unbeabsichtigten Nebenwirkungen.

Um diese Fragen zu beantworten, wurden zunächst alle Ende 2005 zum Verkauf angebotenen Automodelle in Hinblick auf mögliche Autowechsel analysiert, welche durch ein absolutes bzw. relatives Design eines Bonus-Malus-Systems gefördert würden. Für diese möglichen Wechsel wurden die damit einhergehenden Auswirkungen auf die CO_2-Emissionen betrachtet. Aus der durchgeführten Befragung wurden Daten von 326 potentiellen Neuwagenkäufern herangezogen und es wurde deren Bereitschaft untersucht, ihr Kaufverhalten aufgrund von Rabatten zu ändern.

Die Befragungsergebnisse zeigen ein gewisse, wenn auch begrenzte Bereitschaft der Konsumenten, ihr Verhalten zu ändern, um einen Anreiz zu erhalten. Zusammen mit der Analyse des Automarktes zeigen sie jedoch, dass Massnahmen wie Bonus-Malus-Systeme das Dilemma mit sich bringen, möglichst viele Käufer anzusprechen und gleichzeitig unerwünschte Nebenwirkungen zu begrenzen. Dieses Dilemma ist in der Komplexität des Automarktes und der Heterogenität der Konsumentengruppen begründet. Um das optimale Design solcher Massnahmen zu finden, sollten Autokaufmodelle zur Bewertung dieser Massnahmen eine sehr detaillierte Autoflotte beinhalten und Käufersegmente nach relevanten psychologischen Faktoren differenzieren.

Eine zweite Studie wurde durchgeführt, um die relevanten psychologischen Variablen zu identifizieren, welche die CO_2-Emissionen von gekauften Autos erklären. Zudem untersuchte diese Studie, welche Charakteristika die Befragten mit treibstoffsparsameren Autos verbinden und wie sie diese Charakteristika bewerten. Ausgehend von Befunden psychologischer Forschung zu Umweltverhalten wurde ein Modell psychologischer Faktoren untersucht, welches die Theorie des geplanten Verhaltens und das

Normaktivationsmodell integriert. Symbolische Motive wurden als zusätzlicher Einflussfaktor aufgenommen. Dieses Modell wurde mit Befragungsdaten von 302 Personen getestet, welche seit 2002 ein neues Auto gekauft hatten.

Die Ergebnisse zeigen, dass die CO_2-Emissionen der Autos der Befragten direkt beeinflusst werden durch (1) die Bewertung von weniger Autoleistung und kleinerer Grösse, welche die Befragten häufig mit treibstoffsparsameren Autos verbinden, (2) durch die persönliche Norm, ein sparsameres Auto zu kaufen und (3) durch die entsprechende wahrgenommene Verhaltenskontrolle. Wichtige Voraussetzungen für diese Prädiktoren sind wiederum (1) das Bewusstsein für Probleme wie Klimawandel und Abhängigkeit von fossilen Energien sowie (2) die wahrgenommene Wirksamkeit eigener Handlungsoptionen, um etwas gegen diese Probleme zu unternehmen. Demgegenüber hemmen symbolische Motive eine Aktivierung einer persönlichen Norm, ein treibstoffeffizientes Auto zu kaufen, und beeinflussen die Bewertung von weniger Autoleistung und kleinerer Grösse negativ.

Eine dritte Studie sollte theoretische Einsichten in die Natur dieser psychologischen Konstrukte liefern. Dazu wurden Gründe für die Kluft zwischen Absicht und tatsächlichem Verhalten untersucht. Konkret wurden psychologische Faktoren, welche die angegebene Wichtigkeit des Treibstoffverbrauchs beeinflussen, mit den psychologischen Faktoren verglichen, welche das tatsächliche Verhalten erklären. Aus der durchgeführten Befragung wurden Daten für (1) potentielle Neuwagenkäufer ($N_1 = 265$) und (2) Besitzer kürzlich gekaufter Neuwagen ($N_2 = 302$) herangezogen. Zudem sollte die Studie Konsequenzen möglicher Indikatoren für die CO_2-Wirkung eines Verhaltens aufzeigen, welche Ressourcen und Bedürfnisse aufgrund der individuellen Lebenssituation berücksichtigen. Dies sollte Hinweise für die Auswahl und das Design eines sinnvollen Indikators liefern. Für das Verhalten wurden vier Indikatoren betrachtet, welche Ressourcen und Bedürfnisse, auf welche Haushaltstyp und sozioökonomischer Status schliessen lassen, unterschiedlich berücksichtigen. Nicht zuletzt wurden mit der Studie praktische Erkenntnisse angestrebt, die zu einer wirksameren Förderung treibstoffeffizienter Autos beitragen können.

Die Ergebnisse zeigen, dass die Befragten sich bei der Beurteilung ihrer Intention, auf den Treibstoffverbrauch zu achten (operationalisiert durch die Wichtigkeit des Treibstoffverbrauches beim nächsten Autokauf), vor allem an einem inneren Gefühl der Verpflichtung orientieren. Symbolische Motive wirken dabei hemmend. Keine signifikanten Effekte wurden für die wahrge-

nommene Verhaltenskontrolle sowie für die Bewertung von weniger Autoleistung und Grösse beobachtet, welche nach der zweiten Studie beim tatsächlichen Autokauf signifikanten Einfluss auf die CO_2-Emissionen zeigten. Die Unterschiede zwischen den Faktoren, welche Intention beeinflussen, und denen, welche das tatsächliche Kaufverhalten erklären, sind vor allem in der Natur der verschiedenen Faktoren begründet, d.h. in ihrer prozeduralen Nähe zum Verhalten.

Vergleiche verschiedener Indikatoren für die CO_2-Wirkung der Autowahl einer Person zeigen, dass die Ergebnisse deutlich von der Wahl des Indikators abhängen. Dies ist von Bedeutung für die Evaluation von Massnahmen zur Verhaltensänderung, welche verschiedene Gruppen ansprechen, die sich in ihren Bedürfnissen und verfügbaren relevanten Ressourcen deutlich unterscheiden. Generell sollte ein Verhaltensindikator sorgfältig und in Hinblick auf die spezifischen Charakteristika des jeweiligen Verhaltens ausgewählt werden. Ein Indikator, der die CO_2-Auswirkung je nach Haushaltstyp korrigiert und gleichzeitig andere Autos im Haushalt berücksichtigt, scheint Unterschieden im Autokaufverhalten aufgrund der Lebenssituation der Konsumenten besser gerecht zu werden als Indikatoren, welche (a) die CO_2-Auswirkungen des Kaufverhaltens einer Person absolut beurteilen, (b) den sozioökonomischen Status des Haushaltes einer Person berücksichtigen sollen oder (c) nur das zuletzt gekaufte Auto berücksichtigen.

Massnahmen, welche den Kauf effizienter Autos fördern sollen, gewinnen an Effektivität, wenn sie an den psychologischen Faktoren ansetzen, welche in der zweiten und dritten Studie als relevant aufgezeigt wurden. So sollte die Entwicklung und Aktivierung einer persönlichen Norm, ein sparsameres Auto zu kaufen, unterstützt werden, indem sichergestellt wird, dass die Konsumenten sich der Probleme bewusst sind, die mit dem Treibstoffverbrauch verbunden sind. Zudem sollten Massnahmen dafür Sorge tragen, dass die Konsumenten ihre eigenen Kaufentscheidungen wirklich mit diesen Problemen verbinden, d.h. dass sie ihre jeweiligen Handlungsoptionen, etwas zur Lösung des Problems beizutragen, erkennen (wahrgenommene Wirksamkeit des eigenen Verhaltens). Ausserdem ist es wichtig, den sozialen Kontext zu stärken, so dass die Intention, ein sparsameres Auto zu kaufen, (mehr) Unterstützung aus dem Umfeld erfährt (soziale Norm). Zum Beispiel können finanzielle Anreize die soziale Erwünschtheit des Kaufes effizienter Autos hervorheben. Ebenso sollten anerkannte Personen und Institutionen als Vorbilder beim Kauf effizienter Autos wahrgenommen werden können. Dabei kann der öffentliche Sektor eine führende Rolle übernehmen

und Treibstoffeffizienz zu einem prominenten Auswahlkriterium für seine Autoflotte machen. In Hinblick auf den Einfluss symbolischer Motive ist es wichtig, die Verschiebung symbolischer Werte von traditionellen Charakteristika wie Autogrösse und -leistung hin zu Treibstoffeffizienz zu beschleunigen. Dazu sollte Treibstoffeffizienz aktiv als populäre Eigenschaft gefördert werden, welche sich mit den Bedürfnissen der Konsumenten in Hinblick auf andere Autocharakteristika vereinbaren lässt. Zudem kann Treibstoffeffizienz an Popularität gewinnen, indem es mit intelligenter Technologie in Verbindung gebracht wird, sei es mit dem intelligenten Einsatz optimierter konventioneller Technologie oder mit neuer alternativer Technologie.

Damit jedoch die tatsächliche Umsetzung der Intention, ein sparsameres Autos zu kaufen, in Verhalten sichergestellt wird, ist es entscheidend, die wahrgenommene eigene Verhaltenskontrolle der Konsumenten zu stärken. Sinnvoll ist dazu die Informationen der Konsumenten, dass solche Autos nicht notwendigerweise kleiner sein müssen oder dass heutzutage auch die Autos mit den kleinsten Motoren über genügend Leistung verfügen, um andere Autos, wenn nötig, sicher zu überholen oder um typische Steigungen zu bewältigen. Ausserdem sollten Informationen und Handlungshinweise, wie zum Beispiel Energieetiketten, den Konsumenten helfen, effiziente Autos besser identifizieren zu können. Im Allgemeinen sollten Massnahmen, die an verschiedenen relevanten Faktoren ansetzen und sich gegenseitig unterstützen, kombiniert werden (z.B. fiskalische Massnahmen kombiniert mit Informationskampagnen, der Kennzeichnung effizienter Autos und einer konsequenten Umsetzung von vorbildlichem Verhalten durch den öffentlichen Sektor).

Chapter I

Introduction: An overview of the dissertation

1 Introduction

Climate change and the dependence on fossil energy sources are among humanity's greatest present challenges. One of the major energy consuming and CO_2 emitting sectors worldwide is road transport (IEA, 2006; IPCC, 2007a). In order to reduce fossil fuel consumption and thus CO_2 emissions resulting from individual motorized transport, three main routes can be followed: (1) reducing demand, i.e., the number of vehicle kilometers, (2) reducing energy intensity per vehicle kilometer, and (3) reducing CO_2 intensity of energy by using renewable energy sources (cf. de Haan, Peters, & Scholz, 2007). This thesis relates to the second option.

Several of the strategies available for reducing energy intensity per vehicle kilometer, (e.g., a reduction in car or engine size, improvements to the internal combustion engine, or the use of hybrid power trains to recuperate braking energy) lead to an increase of fuel efficiency of the vehicle (cf. de Haan et al., 2007). Increasing fuel efficiency of new vehicles has been identified as one of the most significant elements for reducing energy consumption and CO_2 emissions of road transport (IEA, 2006; IPCC, 2007a). Technological improvements will continue to be necessary. However, consumer adoption of fuel-efficient cars is also required in order to tap the potential for efficiency improvements rendered possible through better technologies (DeCicco, 2006; cf. Zachariadis, 2006). Even among vehicle models using conventional technology, the difference in emissions between the engines with the lowest and the highest CO_2 emissions often exceeds 50% (de Haan, Mueller, & Scholz, 2009). Promoting the purchase of fuel-efficient new cars is a decisive strategy for increasing the efficiency of the whole car fleet. It can be assumed that each car will be on the road for on average of 160'000 km (cf. de Haan et al., 2009) and that gains in fuel efficiency will show effect over the whole lifetime of a vehicle. Thus, a shift of new car buyers to a more efficient version of their preferred car model would already mean a significant impact on the overall fuel consumption and CO_2 emissions of road transport. Hence, from the abovementioned strategies for increasing fuel efficiency of new vehicles, we do not focus on consumers' adoption of new technologies but rather on their general choice of fuel-efficient vehicle models, whether it be by choosing a smaller car size, a smaller engine or optimized engine technology.

Instruments to change consumers' car choices have been discussed both in scientific literature (e.g., Boardman, Banks, & Kirby, 2000; Greene, Pat-

terson, & Singh, 2005) and by various governments (European Union, 1995, 1999). The European Union, for example, includes consumer information and fiscal measures in its strategy to reduce CO_2 emissions from cars (EU, 1995). As concrete instruments, the labeling of fuel-efficient vehicles (see, e.g., Boardman et al., 2000) and feebate systems, i.e., combining fees for the purchase of highly fuel-inefficient vehicles with rebates for very efficient ones are proposed (see, e.g., Johnson, 2006; Train, Davis, & Levine, 1997).

To change or promote a behavior effectively, it is necessary to know the psychological factors which decisively influence the respective behavior (e.g., McKenzie-Mohr, 2000). Hence, the choice and design of any intervention program should be based on a systematic problem analysis guided by theory. However, studies under the topic of car purchase which integrate a pool of variables derived from psychological theory are rare. Research to identify factors affecting car choice has been dominated by economists and market researchers (Choo & Mokhtarian, 2004). These vehicle-type choice models traditionally forecast the discrete choice of a car segment or vehicle type defined by make and model (resulting in categories such as subcompact, small, compact, mid-sized, full-size, luxury, sports, minivan/van, and SUV). However, for most car models, a large variety of subtypes are available which differ according to size, engine capacity, etc. and which consequently also differ in fuel consumption (de Haan et al., 2009). Thus, traditional research has not studied vehicle choice in the detail necessary with regard to fuel consumption or CO_2 emissions.

Moreover, the vehicle-type choice models developed so far have primarily differentiated consumers by their sociodemographic characteristics (Choo & Mokhtarian, 2004). Sociodemographic variables can be indicative, e.g., of personal capabilities and resources and can, therefore, be relevant for specific behaviors which depend on particular capabilities and resources (Stern, 2000). Moreover, we argue that factors such as household type and socioeconomic status influence particular behaviors, as they can be indicators of certain needs. However, they are not sufficient to predict differences in attitudes, beliefs and norms, which have been proven as relevant predictors of behavior (e.g., Anable, Lane, & Kelay, 2006).

The incorporation of psychological factors is a rather new approach in car choice modeling and in choice modeling in general (Ben-Akiva, McFadden, Gärling, Gopinath, Walker, Bolduc et al., 1999; Choo & Mokhtarian, 2004). Choo and Mokhtarian (2004) showed that the inclusion of psychological factors such as attitudes, personality and lifestyle substantially contributes to the

predictive power of models of vehicle-type choice. However, additional studies based on relevant psychological theory are necessary to identify the psychological factors underlying car choice behavior and, thus, the variables needed in such models and those which should be addressed with practical interventions.

The main objective of the present dissertation is to close the abovementioned knowledge gap by exploring the psychological factors that influence the CO_2 impact of a person's car choice. On the one hand, the results may help to improve models to explain and forecast car choice with respect to fuel consumption and CO_2 emissions. Such models are useful to evaluate measures aimed to promote the purchase of fuel-efficient vehicles. On the other hand, the results deliver recommendations for an effective design of such measures.

This introduction provides background information to the dissertation project. First, terminology which is relevant to the topic of fuel-efficient vehicles is introduced (Section 2) before the political context and embedding of the thesis are sketched (Section 3). Subsequently, the specific characteristics of the car purchase decision are outlined and an overview of the focal determinants of car choice is provided (Section 4). This thesis concentrates on two types of determinants of car choice with regard to fuel consumption and CO_2 emissions: psychological factors (Section 4.1) and sociodemographic variables (Section 4.2). Next, an overview of the specific aims of the studies contributing to the overall objective of this thesis is given (Section 5). Finally, the methodological approach is briefly outlined (Section 6).

2 Fuel consumption vs. CO_2 emissions - A few words about the terminology

In this thesis, several terms with similar meaning are used with regard to the topic of fuel-efficient vehicles. This section presents the applied terminology.

Fuel is any material that is burned or otherwise modified to obtain *energy.* The terms fuel or energy consumption are used synonymously throughout the thesis. We do not consider alternative fuels here but focus on lowering both fuel consumption and CO_2 emissions by reducing consumption of conventional fuels. Therefore, we can simplify that *fuel* or *energy consumption* of a vehicle is directly related to its *CO_2 emissions*. A cautionary remark

about the common use of fuel consumption in volumetric units is necessary. Due to the higher energy density per volume of diesel fuel, the use of volumetric units slightly obscures the link between fuel and energy consumption. This might lead to an overestimation of the benefits of diesel fuel in saving energy by consumers. Therefore, *CO_2 emissions* is used as a reliable indicator of the energy demand of cars operated with gasoline or diesel fuel.

Finally, the terms *fuel economy* and *fuel efficiency* have to be distinguished. Fuel economy relates to the fuel consumption of a vehicle for a given distance. Fuel efficiency of a vehicle can be defined in two ways. Absolute fuel efficiency is based strictly on energy consumption per distance and, thus, corresponds to fuel economy. Relative fuel efficiency normalizes energy consumption by a given car utility, e.g., by floor space or curb weight as proxies for transport utility (cf. Chapter II).

In the first study of this thesis (Chapter II), both concepts of fuel efficiency will be used and compared with regard to their consequences for feebate schemes. In the subsequent two studies (Chapter III and IV), we address an audience which might not be familiar with these concepts. Hence, we replaced the term "fuel-efficient vehicle" with the phrase "more fuel economical vehicle" to include the relative idea of fuel efficiency. Accordingly, the term "more fuel economical vehicle" designates a vehicle that uses less fuel than other cars to drive a given distance. This can be achieved either by choosing a smaller vehicle size or by choosing a vehicle which uses less fuel than comparable vehicles (with respect to functional vehicle parameters, such as vehicle size, number of seats, or luggage capacity) due to an engine with smaller size or optimized technology.

3 Political context and embedding of this thesis

The strategy of the European Union to reduce CO_2 emissions from cars (EU, 1995) consists of three pillars: (1) voluntary agreements with manufacturers to decrease average CO_2 emissions of new car registrations; (2) consumer information, with compulsory energy-labels for all new cars as its most important aspect; and (3) fiscal measures to promote the purchase of more efficient cars.

Switzerland, the research setting for this thesis, follows the strategy of the EU (cf. de Haan, Mueller, Peters, & Hauser, 2007). In 2002 an agreement was reached with auto-schweiz, the association of Swiss car importers, to re-

duce average fuel consumption of new car registrations by 3% per year from 8.4 l/100 km in 2000 to 6.4 l/100 km in 2008. Further, booklets reporting fuel consumption of all car models on the market as well as efficiency rankings and an energy label for all new cars on display in showroom floors have been introduced for consumer information. The label applies a relative definition of energy efficiency that relates the amount of energy needed to curb weight, which acts as a surrogate for car utility. Based on this definition, every vehicle is assigned to one of seven classes from A (highly efficient) to G (highly inefficient). With regard to the third EU pillar, the Swiss government is currently discussing the implementation of feebate systems. In general, the topic of promoting fuel-efficient vehicles to reduce fuel consumption and CO_2 emissions of road transport has been intensely discussed by different stakeholders in the recent years.

The project in which this thesis is embedded was launched by ETH Zurich to study relevant factors influencing the purchase of fuel-efficient vehicles and possible effects of conceivable measures to change this purchase behavior. It has been conducted under the sponsorship and collaboration of the association of Swiss car importers (autoschweiz/ auto-suisse), the association of the Swiss oil industry (Erdöl-Vereinigung/ Union Pétrolière) and, within the framework of a separate research project, the Swiss Federal Office of Energy. Exchange with these experts through regular meetings was very fruitful to the whole project and enabled a mutual learning process.

4 Vehicle choice and its determinants

In this thesis, we focus on those determinants which influence vehicle choice in terms of fuel consumption and CO_2 emissions. Vehicles do not belong under the classification of everyday consumption and can be regarded as major investments. The high observability of this product class as well as emotions associated with cars contribute to a state of "ultra-involvement" for many consumers, i.e., to a continuous attention to communication and information about vehicles (Abramson & Desai, 1993). In the vehicle purchase decision itself, consumers are confronted with a vast number of potential alternatives and many decision attributes. The concept of bounded rationality (Simon, 1957) describes how humans make decisions in such situations, given limited time, knowledge and capacity to process information. They neces-

sarily simplify the decision situation by focusing on certain aspects and neglecting others.

With regard to the decision criterion fuel consumption, economic studies assume that consumers consider fuel consumption rationally in their car use and purchase decisions with regard to the costs of gasoline over time (Kurani & Turrentine, 2004). However, interviews conducted with automobile buyers suggest that consumers lack the basic knowledge for such rational decision-making (Turrentine & Kurani, 2007). Instead, there is evidence that "the value of fuel economy is more than differences in fuel costs, but includes other symbols, meanings, and values" (Turrentine & Kurani, 2007, p. 1222). Thus, it is relevant to study the psychological factors which determine if fuel economy is important to consumers during car purchase.

Besides psychological variables, other types of variables might also influence those aspects which are considered in the decision processes and those which are neglected. As previously outlined, traditional car choice models usually include sociodemographic variables (cf. Section 1). On the one hand, these variables can be regarded as indicators for personal capabilities and resources (cf. Stern, 2000) such as money or knowledge. On the other hand, the sociodemographic characteristics of an individual and his or her household may indicate needs which are relevant in the purchase decision, such as the need for luggage capacity or for a specific number of seats.

4.1 Psychological factors

Psychological factors or drivers which are used as explanatory concepts for understanding behavior include constructs like cognitions, motives, values, norms and attitudes (Scholz, 2009). What is considered a driver depends very much on the theoretical approach and the underlying conception of a human being.

As studies on psychological factors of environmental car purchase are rare, we draw on general research of environmental behavior to derive theoretical assumptions regarding the influence of such variables on car purchase with regard to fuel consumption and CO_2 emissions. The most frequently applied theories in the field of environmental behavior are the theory of planned behavior (TPB, Ajzen, 1991) and the norm-activation model (NAM, Schwartz, 1977), which focus on different determinants to explain behavior (cf., e.g., Bamberg & Möser, 2007; Matthies, 2005).

In order to better account for the role of the various determinants proven to influence environmental behavior and in order to understand the underlying preconditions and processes, a promising trend is to combine both theoretical frameworks (cf. Bamberg and Möser, 2007; Homburg and Matthies, 1998). In this thesis, we transfer the combination of both frameworks to the case of environmental car purchase. As a new component beside the TPB and NAM components, we added symbolic motives, i.e., motives to express one's self and one's social position by means of one's car, to account for the special characteristics of vehicles (Steg, 2005).

Table 1.1. Psychological variables which are studied within this thesis with regard to their influence on environmental car purchase

Psychological variables	Type of driver	Theoretical background	Short definition
Problem awareness	Belief/Cognition	NAM (Schwartz, 1977)	Awareness of a problem
Perceived behavioral control	Belief/Cognition	TPB (Ajzen, 1991)	Person's perceived power to perform the behavior
Response efficacy	Belief/Cognition	NAM (Schwartz, 1977)	Perception that own behavioral options have an effect on the problem
Social/subjective norm	Norm	TPB (Ajzen, 1991); NAM (Schwartz, 1977)	Perceived expectations of important others
Personal norm	Norm	NAM (Schwartz, 1977)	Strong intrinsic feeling of obligation to engage in a specific behavior
Attitude	Attitude	TPB (Ajzen, 1991)	Overall evaluation of the behavioral consequences
Symbolic motives	Motive	Dittmar, 1992; Steg, 2005	Motives to express one's self and one's social position by means of material possessions

Table 1.1 presents the corresponding set of variables to be studied. Besides the theoretical background, a short definition and the type of driver to which the respective variables can be assigned are given. In the following, we will shortly introduce these types of drivers and the specific constructs that are in the focus of our study.

Belief/Cognition

Beliefs deal with a "person's understanding of himself and his environment" and can be defined as

> "the subjective probability of a relation between the object of the belief and some other object, value, concept or attribute. Thus, a person may believe that he possesses certain attributes […], that a given behavior will lead to certain

> consequences, that certain events occur contiguously, etc." (Fishbein & Ajzen, 1975, p. 131).

Beliefs are formed by human data processing, including perception, inference, and judgment. This process as well as its product is denoted as cognition (Häcker & Stapf, 1998). Specific beliefs or cognitions mentioned in Table 1 are problem awareness, response efficacy, and perceived behavioral control.

Problem awareness denotes the perception or knowledge that the environment is threatened by ecological problems (Matthies, 2004).

Response efficacy relates to the perception of one's own behavioral options that have an effect on the problem. In a broader view, this construct includes the awareness that one's own behavior has an effect and, therefore, can make a difference. This construct has appeared in literature under different labels, e.g., as internal attribution (e.g., Bamberg & Möser, 2007), efficacy (e.g., Kerr, 1992), response efficacy (e.g., Lam & Chen, 2006), or perceived (consumer) effectiveness (e.g., Thøgersen & Ölander, 2006). As we are especially interested in the aspect of perceiving that one's own behavior can contribute to solving or mitigating the problem in question and as we focus the operationalization of this construct on this dimension, we prefer the term response efficacy.

The concept of response efficacy has to be distinguished from Ajzen's (1991) concept of *perceived behavioral control (PBC)*. This belief is defined as a person's perceived power to perform the behavior due to non-motivational factors such as availability of opportunities and resources.

Norm

Norms are beliefs as well, according to the abovementioned definition. They are beliefs about how we ought to act (e.g., Schwartz & Howard, 1982). Thus, this construct is characterized by a moral or normative component, i.e., by a feeling of obligation. Because of this important characteristic, which does not belong under the general belief concept, we introduce the norm concept separately.

According to the degree of internalization, personal norms and social norms are distinguished (Thøgersen, 2006). A *personal norm* is defined by Schwartz (1977) as an inner feeling of moral obligation to perform a specific action in a particular situation. Individuals adhere to personal norms for in-

ternal reasons, i.e., to be consistent with internalized values or conceptions of right and wrong (Thøgersen, 2006).

Social norms relate to group expectations to perform the respective action or to refrain from doing so (e.g., Schwartz & Howard, 1982). They are related to the individual's perspective by terms such as "subjective" (e.g., Ajzen, 1991) or "perceived" (e.g., Schwartz & Howard, 1982). On the one hand, it is assumed that they are complied with because of real or imagined social pressure (Ajzen, 1988; Thøgersen, 2006). On the other hand, people might follow social norms due to their informative content regarding appropriate behavior in ambiguous situations (Fuhrer & Wölfing, 1997). That is

> "social norms may not only provide information whether a specific behavioral option is morally right or wrong but also whether it is beneficial or easy to perform" (Bamberg & Möser, 2007, p. 17).

In this regard, it may be helpful to discriminate between *descriptive* and *injunctive* social norms (s. Ajzen, 2007; Cialdini, Reno, & Kallgren, 1990). Descriptive norms describe what most people do, i.e., what is typical or normal behavior, and thereby provide evidence about what might be adaptive behavior (Thøgersen, 2006). Injunctive norms describe what most others approve or disapprove of and thus what might be rewarded or punished through the reactions of others (Cialdini et al., 1990).

Attitude

The TPB (Ajzen, 1991) defines an attitude towards a behavior as an overall evaluation of its consequences, conceptualized as expectancy-value model. According to this model, salient expectancy beliefs about the likelihood that a behavior results in particular consequences and the evaluation of those consequences are assumed to underlie the overall evaluation of the behavior.

Besides this definition within the TPB, attitudes have become a very broad and differently defined concept in the general literature (cf. Scholz, 2009). However, as this thesis uses the attitude construct as defined by Ajzen (1991), we do not address these other concepts.

Motive

A motive is a relatively stable trait which describes how a person values the importance of a particular type of goal (Heckhausen, 1989). Heckhausen (1989) points out that motives are considered socially acquired, i.e., physiological and inherent needs are not referred to by the concept.

For car use as well as for the purchase of hybrid cars, studies have suggested that *symbolic motives* play a decisive role (for car use: cf. Steg, 2005; for car purchase: Choo & Mokhtarian, 2004; Turrentine & Kurani, 2007). Symbolic motives refer to the fact that material possessions like cars fulfill an important symbolic function in the expression of one's self and of one's social position or group membership (Dittmar, 1992). Accordingly, the strength of a person's symbolic motives influences how much importance or value she attaches to vehicle criteria such as car size and power or other criteria which can fulfill a symbolic function, i.e., a function to express identity. Choo and Mokhtarian (2004) found drivers of luxury cars to be overrepresented among groups with high education and higher income and to be associated with a status-seeking lifestyle. Thus, in the public perception, status still seems to be considerably connected to vehicle size and performance. However, strong symbolic motives do not necessarily translate to higher fuel consumption and CO_2 emissions due to larger and high powered vehicles. The direction of influence depends on which vehicle characteristics possess symbolic value for a person. A study by Turrentine and Kurani (2007) indicates that fuel economy can be a symbolic feature as well if car drivers view resource conservation as important values.

4.2 Sociodemographic variables

Evidence suggests that the relevance and role of sociodemographic variables in comparison to psychological variables depend on the particular behavior (cf. Stern, 2000). Sociodemographic variables can be relevant for behaviors which depend on particular resources or are influenced by needs varying according to a person's living situation.

When evaluating actual environmental behavior, whether for individuals, for groups or for whole states, it is a difficult and inherently value-driven judgment on how one decides if someone's environmental impact is above or below average. On the individual level, one could argue that environmental behavior should be judged absolutely with regard to its impact. For various behaviors which are considerably influenced by needs and resources due to a person's living situation, it could also be argued that it is helpful to consider if a person's environmental impact is above or below average compared to a reference group defined by equal circumstances. Such a relative indicator could help to better evaluate the impact of measures to promote specific be-

havior for certain groups which have a very strong impact due to their living situation.

With regard to car purchase behavior, a person living in a large household with children might buy a larger car than a person living in a small household. Nevertheless, within this needed car-size range, the first person could still buy a relatively fuel economical, i.e., a fuel-efficient vehicle. This pro-environmental behavior, however, might not be identified adequately if one regards behavior without accounting for people's living situation.

Hence, in this thesis, constraints by resources and needs due to a person's living situation are considered when studying the influence of psychological variables. A literature overview (Chapter IV) suggests that mainly household type and socio-economic status are the indicators of relevant resources and needs that are assumed to influence the choice of vehicles with regard to fuel consumption. Socio-economic status, in turn, is based on variables such as income, education and occupational level.

In this thesis, we account for these characteristics by applying various proxies of CO_2 impact of a person's car purchase behavior. These proxies differ depending on how (and if) they take resources and needs indicated by household type and socio-economic status into account. That is, they normalize CO_2 emissions by different factors that account for household type or socio-economic status.

5 Objective of the thesis and respective aim of the studies

The aim of this thesis is to identify the relevant psychological variables influencing car choice behavior of new car buyers with regard to fuel consumption and CO_2 emissions. An inclusion of relevant psychological variables into models forecasting vehicle choice with regard to these characteristics should add to the predictive power of such models and improve their feasibility to evaluate measures aimed at changing purchase behavior. On the other hand, the variables also present starting points for creating effective interventions to change vehicle choice.

The studies presented in this thesis contribute to this objective as follows.

By analyzing and discussing the possible effects, including counteracting effects, of feebate systems, the first study points out the complexity of the

vehicle market, consumer heterogeneity, and consequences of fiscal measures to promote the purchase of fuel-efficient vehicles (Chapter II).

As mentioned in Section 1, this thesis does not focus on consumers' adoption of new technologies or on measures to promote this specific change. However, in the overarching project in which this thesis was embedded, another branch dealt with possible effects, including counteracting effects, of measures promoting hybrid vehicles. The Appendix presents the salient results from this related study.

Table 1.2. Overview on the studies conducted within this thesis, their main research questions and conclusions

Study (Chapter)	Content of the study Main research qestions	Conclusion
1 (II)	**Overview and analysis of the object of research and its environment: the car market and implications for the development of measures to promote fuel-efficient vehicles, illustrated for the case of feebates** Do absolute or relative feebates encourage more consumers to change to vehicles with lower fuel consumption? With regard to relative feebate systems, to what degree would counteracting effects be possible? What has to be accounted for when evaluating possible designs of measures to change car purchase behavior?	Feebate systems to promote fuel-efficient vehicles entail the dilemma of simultaneously addressing more consumers and limiting counteracting effects. This dilemma is rooted in the complexity of the vehicle market and the heterogeneity of the consumer groups. A central recommendation is to differentiate consumers according to the relevant psychological factors when developing policy measures.
2 (III)	**Influence of psychological factors on the choice of new vehicles with regard to fuel economy and CO_2 emissions** How do psychological factors drawn from relevant theory such as beliefs, norms, and attitudes influence the choice of fuel-efficient vehicles? How do these factors interplay with each other? Which characteristics do people associate with fuel-efficient vehicles and how do they evaluate these characteristics?	Factors which directly influence the purchase of fuel-efficient vehicles are identified. Moreover, relevant preconditions as well as inhibiting factors are pointed out which influence the activation and development of the direct predictors .
3 (IV)	**Psychological factors influencing fuel consumption and CO_2 emissions within intended vs. actual car purchase** How do psychological factors such as beliefs, norms, and attitudes influence the intention to consider fuel economy within vehicle purchase? What differences can be observed between factors influencing intention and factors influencing actual behavior? How can they be explained? Can we draw implications with regard to appropriate proxies of CO_2 impact of a person's car purchase behavior? What are the starting points for a better promotion of fuel-efficient vehicles?	This study provides theoretical insights into the nature of the psychological constructs influencing the purchase of fuel-efficient vehicles. Further, it points out the consequences of choosing a proxy of an environmental behavior and delivers hints for possible designs of such proxies. Finally, practical implication are drawn with regard to the promotion of fuel-efficient vehicles.

The second study aimed to identify the relevant psychological variables influencing car choice with regard to fuel consumption and CO_2 emissions (Chapter III). Finally, a third study analyzes and discusses in detail the psychological constructs which play a role when intention to purchase a fuel-efficient vehicle is to be transferred into action (Chapter IV). Moreover,

alternative proxies of CO_2 impact of car purchase behavior, which take sociodemographic characteristics indicating relevant resources and needs into account, are considered. We illustrate their consequences and give hints for their possible design. Finally, we derive practical implications with regard to the better promotion of fuel-efficient vehicles. Table 1.2 gives an overview of the studies, their concrete research questions and their conclusions.

6 Method of the thesis

The data analyzed in this thesis has mainly been provided through a paper-and-pencil survey on mobility and car purchase behavior which we conducted in two waves with a sample of households living in the German- and French-speaking parts of Switzerland. This survey contained, among other items, questions about psychological factors, decision criteria and preferences, acceptance of and susceptibility to measures which are discussed in the context of rising fuel-consumption, vehicles owned by the household, and sociodemographic data.

Table 1.3. Sampling procedure of the survey and the studies underlying this thesis which are presented in the following chapters

	Survey code	**Number of cases**	**Response rate (*N*)**	**Selected sample within the studies[a]**
First wave (two questionnaires)	W1	5890	39.6% (2333)	
first wave: base questionnaire	W1A	3920	40.3% (1581)	Study 1: Potential new car buyers ($N = 326$)
first wave: life history questionnaire	W1B	1970	38.2% (752)	
Willing to participate and reachable in second wave (one questionnaire)	W1& W2	1545 (66.2%)	74.4% (1150)	Study 2 & Study 3, Sample 2: Respondents with vehicle purchased new since 2002 ($N = 302$)
base questionnaire sample	W1A& W2	1060	74.3% (788)	Study 3, Sample 1: Potential new car buyers ($N = 265$)
life history questionnaire sample	W2B& W2	485	74.6% (362)	

[a] Study 3 analyzes two different but partly overlapping samples.

The first wave was conducted in June 2005: two questionnaires, a so-called *base questionnaire* and a *retrospective life biography questionnaire*, were sent out to a sample of 5890 households randomly chosen from the Swiss phone book. Both questionnaires of the first wave include questions

on the sociodemographic characteristics presented in Section 4.2, on the vehicles owned by the household and on preferences for a next car purchase. The base questionnaire further contains questions on the importance of various decision criteria within car purchase, as well as questions on acceptance of and hypothetical reaction to measures aimed to reduce energy consumption in the road transport sector. Furthermore, the life history questionnaire collects data on life events occurring in the past 15 years which could influence car purchase and choice. This life history data is not the focus of this thesis (for analyses of this data please refer to Mueller, de Haan, Peters, and Scholz (2009)). The average response rate for the two surveys of the first wave reached 39.6% (2333 respondents).

The second wave was sent out in June 2006 to 1545 respondents (66.2% of the sample of the first wave) who were willing to participate again and were still reachable under the address in our data base. The questionnaire of the second wave mainly included questions on the psychological variables presented in Section 4.1. Additionally, changes in the vehicle stock of the household were surveyed. This questionnaire was sent back by 1150 respondents (74.4%).

The studies presented in this thesis all focus on new car buyers, as this is the target group important to change the vehicle fleet on the roads (cf. Section 1). However, the studies use different subsamples depending on the research questions of the study, i.e., depending on the respective items from the three questionnaires to be analyzed. Table 1.3 shows the detailed numbers for the survey and describes the subsamples selected for the different studies.

Chapter II

Feebates promoting energy-efficient cars: Design options to address more consumers and possible counteracting effects

Abstract

An increasing number of countries have implemented or are evaluating feebate systems in order to reduce energy consumption of new vehicle registrations. We distinguish between absolute feebates based strictly on a vehicle's energy consumption and relative feebates normalizing energy consumption by a given car utility. This paper analyzes whether absolute or relative feebates encourage more consumers to change to vehicles with lower energy consumption. We combine an analysis of all car models on sale at the end of 2005 with survey data from 326 potential new car buyers. Analysis of the car fleet with regard to behavioral changes assumed as realistic shows that relative systems succeed better in offering more consumer groups cars that are eligible for incentives. Survey results suggest that consumers show some, but limited, willingness to change behavior to obtain an incentive. However, a relative system potentially allows people to switch to cars with higher relative efficiency without actually lowering absolute CO_2 emissions. We discuss this inherent dilemma of simultaneously addressing more consumers and limiting counteracting effects. In order to find the optimal trade-off, we suggest assessing different parameters operationalizing vehicle utility by means of micro-simulation with detailed car fleet and differentiated consumer segments.

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1 Introduction

There are many reasons to reduce consumption of non-renewable energy resources, e.g., limiting global CO_2 emissions and hence limiting the greenhouse effect, reducing dependence on energy from politically unstable regions, leaving a higher share of non-renewable resources for future generations and reducing dependence on them at all. Along with the complementing strategies of shifting to renewable energy sources and reductions in demand, a drastic increase in energy efficiency is needed for significantly reducing consumption of non-renewable energy resources. In OECD countries, the projected incremental oil demand in 2004-2030 is almost exclusively driven by the transport sector (IEA, 2006, p. 88). In the Alternative Policy Scenario of IEA (2006), policies in the transport sector account for 59% of global oil savings over the projection period (IEA, 2006, p. 178). Measures aimed at improving new vehicle fuel efficiency contribute more than two-thirds of these oil savings in the transport sector (IEA, 2006, p. 223).

While engineers make stunning progress in improving efficiency of internal combustion engines, a large potential for improvement in energy efficiency persists in increasing consumer adoption of energy-efficient cars (DeCicco, 2006). This delineates the mechanisms of consumer behavior in general and of car purchase behavior in particular as decisive factors in reducing energy consumption.

Feebate systems combining fees for the purchase of highly energy-inefficient vehicles with rebates for very efficient ones are proposed as a feasible instrument to change consumers' car choices (see also Johnson, 2006; Train et al., 1997). They offer various advantages compared to measures like fuel economy standards or fuel taxes (see Greene et al., 2005). Such feebate systems have been widely considered by various governments but have been implemented to a lesser degree (Greene et al., 2005). While a lack of real-world experience exists, various studies have modeled effects of feebates (Langer, 2005).

These studies typically distinguish supply and demand effects. For manufacturers, an adoption of efficiency technologies is assumed depending on the availability and cost of technologies and the amount of saved fees or gained rebates by the efficiency increase. Consumer responses are typically based on price elasticities of demand derived from revealed preference data on purchasing behavior. Vehicle choice is then predicted by rather aggregated approaches on a vehicle segment level (Greene et al., 2005).

In the following, we present a list of the main shortcomings such models exhibit in our view, which originate from required simplifications and assumptions (see also Langer, 2005):

First, these studies neglect the fact that, for most car models, a large variety of subtypes are available which differ in size, engine capacity, etc., and consequently also differ in energy efficiency. Although a few studies (e.g. Davis et al., 1995; HLB Decision Economics Inc., 1999) differentiate a considerable number of vehicle segments (e.g., depending on factors like vehicle type, origin [domestic or foreign], acceleration performance, and technology status [high or low]), the possibilities and consequences of individual changes of purchase behavior need to be studied on an appropriately disaggregated level using a highly detailed car fleet.

Moreover, models reduce the expected effect of feebates to economic aspects, neglecting that consumers might react first and foremost to either the symbolic meaning of feebates, changes in the perception and valuation of energy-efficient vehicles or the understanding of the sense and necessity of such a scheme. Accordingly, Turrentine and Kurani (2007) argue that economic rationality is insufficient as a behavioral model underlying policy making and analysis.

Furthermore, little analysis has been conducted thus far on feebates at the national level. Studies on an international scale suggest that the dominant effect of feebates is due to manufacturers' adoption of efficiency technologies and not to changes in consumers' buying behavior. However, feebates on a national level should not be neglected. Langer (2005) argues that for such feebates, consumer response might be considerably greater, as consumers would be more inclined to change their purchase choice if manufacturers do not offer their previously preferred vehicle with improved energy efficiency by adopting new technology.

Most notably, to our knowledge, the possible implications of consumers' changing behavior have not yet been studied either systematically or in great detail, which might be due to the aggregated nature and focus on the international level – and consequently on the manufacturer aspect – of previous studies. Research on the implementation of measures and technologies to improve energy efficiency has revealed that these measures may exhibit counteractive effects, which could lead to an increase in energy consumption. De Haan et al. (2006) investigated whether the adoption of hybrid cars demonstrates such effects, which in this case could be induced due to lower psychological or social costs. Side effects on either the manufacturer or consumer

side caused by monetary incentives are imaginable as well. In general, the definition of a feebate system influences which consumer groups and vehicle segments are addressed. In particular, it determines which behavior is rewarded, including unintended behavior on the consumer or on the manufacturer side. These aspects are crucial for the efficacy and efficiency of a feebate system.

Various possible types of feebate schemes and design options appear in literature (DeCicco et al., 1993; Greene et al., 2005; HLB, 1999; Johnson, 2006; Train et al., 1997). In general, a feebate system requires a yardstick, i.e., a definition of what is meant by "energy efficiency", so that an energy efficiency score may be computable for each car. By means of this yardstick, eligibility for a rebate or allocation of a fee is defined.

The definition of energy efficiency as a basis for feebates can be derived in two ways. If the policy target, i.e., the main goal of the feebate scheme, is reducing CO_2 emissions per vehicle, the simplest approach would be to relate feebates directly to the policy target (e.g., CO_2 emissions per kilometer). In this paper, such an approach is referred to as an absolute system.

However, an alternative policy base might result in increased policy efficiency by better addressing different consumer groups (Boardman et al., 2000; E.V.A., 1999). For this aim, the alternative policy base, which imperatively needs to correlate with the policy target, requires adjustment to consumer perspectives, in order to facilitate comparisons of energy consumption and thus changes between vehicles within consumers' individual sets of contemplable alternatives. Accordingly, the term relative system denotes an alternative approach basing feebate distribution on energy consumption normalized by a given car "utility", i.e., the amount of energy needed would be divided by a surrogate for this utility, which might be car length (or width or height), floor space, curb weight, number of seats, trunk space, etc.

The second step required when defining a feebate system, i.e., determining which vehicles are affected by a fee or a rebate, can be realized by a discrete classification or differentiation on a continuous scale. Within a discrete classification similar to the classification of household appliances in many European countries, vehicles could be divided into classes from A (highly efficient) to G (highly inefficient), with A-labeled vehicles being eligible for rebates. On a continuous scale, the specific distance of a vehicle's score from a so-called pivot point could determine the size of the fee or the rebate for the purchase of a specific car. The concept of the pivot point is very common in U.S. and Canadian literature (see Greene et al. (2005) for more information).

This paper aims to identify the impacts on consumer behavior of absolute vs. relative feebates as defined above. For the sake of simplicity, only the case of rebates based on a discrete classification common in the EU is analyzed. Of course, differences between full schemes (encompassing both fees and rebates) and such partial ones might exist with regard to efficacy. Comparatively less impacts may occur in partial feebate schemes, as these schemes affect only a part of the vehicles involved in a full system (Greene et al., 2005). Moreover, it may be decisive whether a partial feebate system is realized via fees or via rebates, as varying degrees of impact may arise due to different perceptions of losses or penalties versus gains or rewards (Kahneman & Tversky, 2000).

The first part of this paper introduces an illustrative example of an absolute versus a relative feebate design based on the Swiss energy efficiency labeling scheme in order to illustrate their ability to appeal to different consumer groups. Subsequently, specific behavioral changes offered by the different feebate systems and their possible effects on the policy target are analyzed using the concrete examples. This entails a closer look on psychological concepts and findings from literature which seem relevant for the functionality of feebates. Finally, we present a survey to analyze the willingness of consumers to change purchase behavior under such feebates. In the last chapter, we discuss our findings and present our concluding remarks.

2 Possible changes of purchase behavior induced by different feebate designs

2.1 Addressing of different consumer groups

In this section, we investigate which consumer groups can be potentially addressed by an absolute and by a relative scheme, respectively. The concrete examples presented in this chapter are based on the Swiss energy efficiency labeling scheme classifying vehicles from A (highly efficient) to G (highly inefficient). By definition, class A holds one seventh of all car models on the market. Energy consumption measured in fuel consumption in kilogram per distance is defined as the policy target, and curb weight is used as a surrogate for car utility to calculate the alternative policy base.

In this context, an absolute feebate system classifies vehicles having the lowest energy consumption as A, while a relative feebate system rates cars

with the best energy consumption to curb weight ratio as A. In both examples, a buyer of an A-labeled vehicle receives a rebate of, e.g., EUR 1300 at the time of the purchase. As mentioned above, intuitively, an absolute efficiency measure seems to be the logical and most effective system to reduce energy consumption because it relates directly to energy needed. However, it might only address consumers of smaller cars, considering that those who prefer larger vehicles will not find any A-labeled vehicle in their preferred size-range. A relative system might be more successful in involving more consumer groups.

The following analysis is based on a normative definition of vehicle utility segments and a data set which comprises the 2071 technologically different vehicle types on the market in Switzerland in November 2005. We differentiate distinct utility segments using the parameters *car size class*, *price*, and *engine size*.

Table 2.1. Specification of parameters used to define vehicle utility segments

Parameter	Specification
Car size class	Micro, subcompact, compact, minivan, mid-size, van, full-size, sport utility vehicle (SUV), luxury
Price	< 12'500 EUR, 12'500 - 18'749 EUR, 18'750 - 24'999 EUR, 25'000 - 31'249 EUR, 31'250 - 37'499 EUR, 37'500 - 43'749 EUR, 43'750 - 49'999 EUR, ≥ 50'000 EUR
Engine size	Very small (< 1450 ccm), small (1450 - 1749 ccm), normal (1750 - 2099 ccm), large (2100 - 2549 ccm), very large (≥ 2550 ccm)

Table 2.1 shows the specifications for these parameters. The parameter car size class corresponds to the official classification of the association of Swiss car importers, auto-schweiz, which reflects European consumer perception according to expert judgment. The class sport utility vehicle includes small all-terrain vehicles, crossover sport utility vehicles (SUVs), and SUVs.

Figure 2.1 shows the occurrence of A-labeled vehicles within the specific utility segments for the absolute and the relative feebate design. Accordingly, the investigated designs differ considerably, with the relative design being more successful in offering A-labeled vehicles over the range of utility segments. Under the assumption that consumers change their purchase behavior within only a limited range, it can be concluded that the relative scheme succeeds better in addressing more consumers. If and to what degree the consumers that would – in principle – be addressed are truly willing to change their purchase behavior due to the incentive, are issues which will be treated later based on data from a survey of potential new car buyers (Sections 3-5).

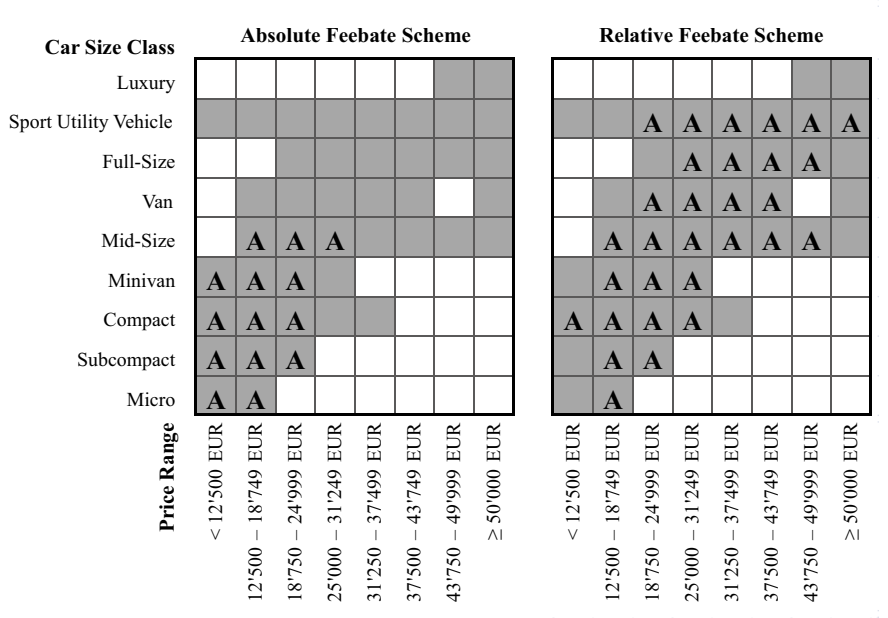

Figure 2.1. Illustration of the occurrence of A-labeled cars within the absolute (left) and the relative feebate scheme (right) over the range of utility segments defined by car size, price, and engine size. For reasons of readability, the dimension engine size is aggregated. A grey cell indicates the occurrence of at least one vehicle in the respective cell defined by car size and price, an "A" indicates the occurrence of at least one A-labeled vehicle.

2.2 Possible changes of behavior

This section introduces the possible behavioral changes of different consumers. With regard to the choice range of consumer groups, former studies interested in the effect of consumer-oriented measures to increase energy efficiency such as the labeling of energy-efficient cars (cf. E.V.A., 1999; Boardman et al., 2000) examine consumers' willingness to change: (i) to a more efficient version within the same model, i.e., with a smaller engine; (ii) to a more efficient model within the same market class; and (iii) to a smaller model, i.e., smaller car size.

Their results show that a significant share of consumers are willing to change their choice and consider other alternatives, with a higher willingness to change within the same model or within the same market class and a lower willingness to change to a smaller model.

Accordingly, in the case of feebates, we assume that consumers would be willing to broaden their choice set only to a limited degree. However, as Figure 2.1 indicates, a feebate design could also induce consumers to select larger cars, although this may seem counterintuitive. A consumer previously intending to buy within a smaller car size class could, if A-labeled cars are available in a larger class, also be encouraged to change to this class.

In order to identify which particular behavior would be rewarded by a specific feebate design, we extend the range of behavioral changes considered by E.V.A. (1999) and Boardman et al. (2000) and study the following behavioral changes assumed to be realistic and likely:

(a) change within the *same utility segment* (within same car size, price segment and engine size);
(b) change to the utility segment defined by the same price segment and engine size but *smaller car size class*;
(c) change to the utility segment defined by the same price segment and car size class but *smaller engine size*; and
(d) change to the utility segment defined by the same price segment and engine size but *larger car size class*.

For the case of a relative policy base (as in our example: ratio of energy consumption to curb weight), such changes increase relative energy efficiency but not necessarily energy economy, which in fact can be adversely affected. The question is to what degree such unintended side-effects would be possible.

2.3 Possible effects of behavioral changes on CO_2 emissions

In this section, the potential effects with regard to absolute CO_2 emissions of the four above-mentioned variants of behavioral changes are explored for the relative feebate design. Combinations of the behavioral changes are not considered in this paper. By definition, an absolute system linked directly to the policy target (i.e., reduction of energy consumption and CO_2 emissions, respectively) does not encourage any changes that would increase this target parameter.

We start with our analysis from the specific vehicles in the car fleet. For each vehicle in the car fleet that is not eligible for a rebate, we identify A-labeled alternatives consistent with the constraints of the above-mentioned behavioral changes. Regarding price, we assume a consumer to consider

alternatives in a range of ± 15% of the purchase price of the specific vehicle. We performed sensitivity analyses to ensure that the magnitude of this range does not influence our main results. For the change to a smaller or a larger car size, the corresponding classes are defined by the following arrangement: "micro", "subcompact", "compact and minivan", "mid-size", "full-size", and "SUV and luxury". As vans do not fit in this ordinal scale, minivan and mid-size were assigned as next smaller, and full-size was assigned as next larger segment.

Subsequently, all possible consumer changes to A-labeled vehicles are assessed as to whether they represent cases that decrease CO_2 emissions-according to the goal of the policy-or cases which do not decrease CO_2 emissions. The latter, which are considered to be unsuccessful in the sense of the policy goal, consist of changes to vehicles with either higher or equal CO_2 emissions compared to the initial car.

Both types of changes are aggregated separately within each utility segment (see Table 2.1). In Figure 2.2, we present the frequency of possible changes increasing CO_2 emissions for the four variants of behavioral changes. For comparison, the number of all possible changes is given in brackets.

Figure 2.2 shows that a significant portion of all possible changes to A-labeled cars within a realistic range go hand-in-hand with a stagnation or an increase of CO_2 emissions instead of the intended decrease. The three most important issues illustrated by the figure are highlighted as follows: First, changes counter to the policy target could occur within all four variants of behavioral changes, even when remaining in the same utility segment. Second, based on our illustrative example, the change to a smaller engine is least vulnerable to being counterproductive. Finally, as expected, the proportion of changes not successful in reducing CO_2 emissions is highest for changes to a larger car size. However, changes to larger cars are not a priori bad, as the changes reducing CO_2 emissions still prevail.

The next sections present the results of a survey tackling the question of whether consumers would be willing to change car purchase behavior for a rebate. We investigated which consumer groups would be willing to change and in which of the above-mentioned ways they would do so (i.e., changing to a smaller car, to a smaller engine, to a larger car). Before we present the conducted study, we give an outline of psychological concepts and findings from literature which seem relevant for the functionality of feebates.

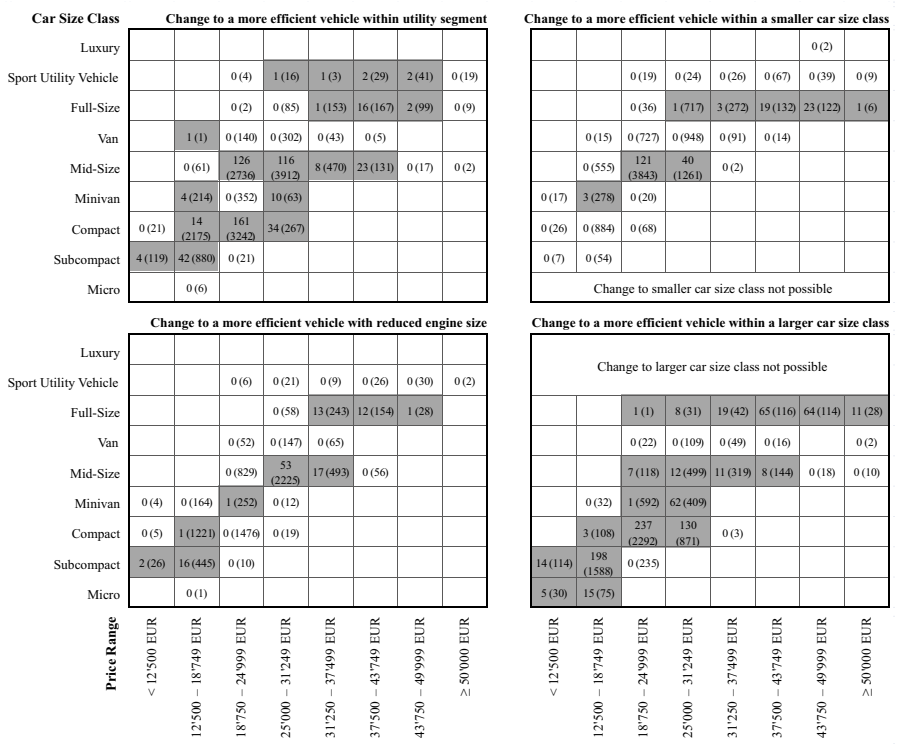

Figure 2.2. Frequency of changes to A-labeled vehicles from all vehicles in a cell that do not decrease CO_2. The number of all possible changes to A-labeled vehicles is given in brackets. For reasons of readability, the utility segments were aggregated over engine size. Empty cells indicate that A-labeled alternatives do not exist for vehicles in the respective cell. A grey cell indicates that from all possible changes starting from the respective cell, at least one change would not decrease CO_2 emissions leading to an unintended side-effect. Possible behavioral changes: (1) remaining within the utility segment, (2) switching to smaller engine size; (3) changing to smaller car size; (4) changing to larger car size. As an illustration, for the case of changing to a larger car size class from a mid-size car with a price between 25'000 and 31'249 EUR and all engine sizes, 499 changes to A-labeled cars are possible, with 12 changes not decreasing CO_2 emissions.

3 Willingness to change purchase behavior for rebates

There are various psychological factors and mechanisms decisive for the question which consumers would be susceptible to financial incentives and what changes of behavior would be likely if a reward is offered. These factors and mechanisms are derived from psychological findings on the perceived value of money and from research on car choice with regard to motivational factors and consumer segmentation.

Psychological research on the perceived value of money has shown that the value function of prospect theory and its generalizations and developments are consistent with people's perception of carriers of value (Kahneman & Tversky, 1979, 2000). This value function has the following salient characteristics: A steeper slope for losses than for gains and diminishing marginal utility, i.e., the marginal value of an amount of money decreases with its size. The steeper slope for losses is relevant with regard to the effect of fees vs. rebates. Accordingly, fees, which represent a loss of money, would have a stronger effect than rebates of equal amount. So, with regard to effects and efficiency, it would be recommendable to implement fees on highly energy-inefficient vehicles. However, it is not the aim of this paper to compare the effects of fees and rebates but rather to determine under which principles the basis of their distribution should be designed. For this aim, a relative difference of effectiveness for fees versus rebates is not relevant.

In our case, the concept of reference dependence in prospect theory is most important. In line with reference dependence, consumers would not perceive the amount of a fee or rebate simply according to its absolute size but rather according to the car price it is related to. Hence, a payment of EUR 1300 should have a bigger effect when linked to a purchase price of, e.g., EUR 15'000 for a small car than to EUR 30'000 for a mid-sized car.

Also, household income might play a role in the effect of a specific amount of payment for consumers. The inclination of a high-income household to change behavior for a rebate of EUR 1300 might be smaller than that of a low-income household. Of course, these two mechanisms might be confounded in the car purchase situation, as households with higher income tend to purchase more expensive cars (Choo & Mokhtarian, 2004).

So, with regard to the financial incentive alone, lower income households should generally be more inclined to change behavior and, in particular, more willing to accept a reduction of car size or of engine size (without simultaneously changing to a larger car) for a rebate. However, a change in

purchase behavior towards larger cars could be realistic – and attractive if linked to a rebate – also for consumers who can not be motivated by a rebate to reduce their preferred level of car or engine size, in particular for consumers preferring larger cars. Of course, for high-income consumers of larger vehicles, the need to change to an even larger car could be less or already satisfied due to diminished financial restrictions. Nevertheless, for families preferring larger cars, it could be very attractive to buy a vehicle with even more space than they would otherwise consider if a rebate was not offered.

It can be argued that the average price differences between vehicle classes that consumers would consider for a change are too big in relation to a rebate of EUR 1300, such that large numbers of changes to a larger car size class are not induced. Indeed, the average price differences between different vehicle classes would not be compensated by the discussed financial incentives. Nonetheless, the argument is flawed in that a disaggregated view of the vehicles on the market (cf. Figure 2.1) shows that the price distributions of two neighboring classes overlap.

Moreover, a rebate could very well be the decisive factor in that even a large price difference is reduced by some crucial amount under which a change to a larger car size class appears possible and attractive. According to prospect theory (Kahnemann & Tversky, 1979, 2000), an additional value is perceived very prominently when a purchase price is reduced by additional discounts, such that customers would be much more inclined to collect this additional value, i.e., the rebate, even though they pay more money in comparison to a smaller car (without a rebate).

However, as mentioned in Section 1, considering only the monetary effect of rebates would fail to grasp the relevant mechanisms of action of such incentive schemes. According to Langer (2005), feebates play a role in drawing consumers' attention to the reason behind the scheme-energy consumption and its consequences. They serve as a signal for "the right choice" and present individual opportunities to act.

But with regard to people's commitment to the respective behavior and these nonmonetary effects, it is crucial that measures to influence behavior are not perceived as unjustified constraints of freedom, which can induce reactance, i.e., that the person shows the contrary behavior. Thus, it is important that people accept the respective measure and hence the aim of influencing their behavior (Homburg & Matthies, 1998).

Acceptance of feebates could also be an interesting indicator with regard to the meaning of a behavioral change for the respondents. Especially for the

behavioral changes which could intuitively lead to unintended effects, a positive correlation between willingness and acceptance (showing that people with higher acceptance of the rationale behind feebates tend to be more willing to change) would indicate that, to a significant degree, consumers assume that their respective changes are in line with the intended objective of the feebate system and thus would not deliberately try to circumvent it. However, there might also be consumers who simply use the opportunity for financial gain knowing that they do not really reduce energy consumption.

Regarding these thoughts, we consider acceptance of feebates and its relationship to the willingness for the different types of behavioral change. In general, we assume acceptance to be positively related to willingness to change behavior in any way, supposing that people take a rebate given by the government as a signal for socially desirable, responsible behavior. We do not expect this general acceptance of rebates to be dependent on the preferred car size.

Additionally, when thinking about changing car purchase behavior, an important topic is considering which function a car fulfills for a person. Research on motivational factors of car use has shown that car use is not only related to instrumental motives but also to important symbolic and affective ones (Steg, 2005). Material possessions like cars fulfill an important symbolic function in the expression of the self and of one's social position or group membership (Dittmar, 1992). The expression of the self may vary widely across socio-demographic groups; however, when social position is expressed by car use or type, it is sensible to assume that, in higher social strata, people are rather inclined or even obliged to drive larger and thus more representative cars.

Choo and Mokhtarian (2004) found drivers of luxury cars to be over-represented among groups with high education and higher income and to be associated with a status-seeking lifestyle. This suggests that this market segment is less susceptible to policies aimed at reducing energy consumption through reduction in car size, as these drivers of larger or luxury cars face accordingly larger psychological and social barriers to change to smaller cars than drivers of lower social positions. Changes to a relatively more efficient car, i.e., one with a smaller engine in their preferred class segment, might, however, seem more realistic for them, as this might not affect the status function of the vehicle to a great degree.

There is also another social group which seems more obliged to drive larger cars than others, especially due to instrumental motives. According to

Choo and Mokhtarian (2004), minivan drivers are over-represented in larger households with children. They might be susceptible to financial incentives but have a more restricted choice set than do smaller households with respect to car size. Accordingly, barriers to switch to smaller vehicles exist despite willingness in principal. However, a change to a smaller engine should seem realistic for them.

Based on these findings and concepts, we are interested, on the one hand, in exploring the general degree of acceptance of feebates and willingness to change purchase behavior as a reaction to such incentives, and on the other hand, we aim to analyze which consumer groups would be willing to change and in which of the possible ways.

We expect buyers of rather small car size classes to state to a greater degree that they would change to smaller cars and smaller engines than would buyers of larger cars (Hypothesis 1). However, we do not assume a relationship between preferred car size class and willingness to change to larger cars. With respect to all types of changes, we expect acceptance of feebates to correlate with the respective willingness (Hypothesis 2). Finally, as the above-mentioned factors are also influenced by socio-demographic factors like household income, education, and persons in household, we also include these variables in the analyses.

4 Survey and sample characteristics

The questionnaire was sent out in June 2005 to 3920 households in the German- and French-speaking parts of Switzerland randomly chosen from the phone book. The survey achieved a response rate of 40.3%. For this study, only the potential buyers of new cars are relevant. Hence, we only selected those respondents who stated that they would *presumably* or *certainly* buy a *new* car within the next ten years. Furthermore, as will be explained in the following, the respondents whose car size preferences could not be integrated on an ordinal scale were excluded.

The 16-page questionnaire included several modules concerning various topics relevant for car purchase and mobility. In the following section, the modules relevant for this study are described before we present the sample's characteristics.

4.1 Questionnaire

In the questionnaire, willingness to change to a smaller engine, a smaller car or a larger car for a rebate was assessed with three items to be answered on 5-point scales. Participants were asked how much they are likely to change behavior in the respective way if they could receive a premium of EUR 1300 for particularly energy-efficient cars. As a rebate for the change to a larger car is not intuitive, it was explained by an example with concrete car models.

Next, nine 5-point scale items measured acceptance of various measures considered conceivable for reducing energy consumption of road transport. Respondents were asked to rate how reasonable each measure was in their view. Two of these items addressed components of feebates: (a) rebates for very efficient vehicles and (b) fees for highly inefficient vehicles. All questions concerning measures to reduce energy consumption of road transport were presented almost at the end of the questionnaire in order to avoid self-selection of participants especially interested in environmental issues or in the specific measures.

In order to measure car size preferences, respondents were asked which vehicle type they preferred for their next car purchase. They could tick two of the following twelve vehicle-type categories: micro, subcompact, compact, mid-size, full-size, luxury, minivan, van, small all-terrain vehicle/crossover SUV, SUV, cabriolet/roadster, sports car/coupe. To ensure that the respondents understood the vehicle size classes in a consistent way, we gave an average of 11 concrete, typical examples for each category. However, as we aim to study the relation of preferred car size with willingness to react to rebates, only the first six categories of this variable, which are unambiguously classifiable in order of vehicle size, are useful. In all, 71.3% of all respondents ticked within the first six categories. With regard to questionnaires in which two categories were ticked, we selected only the cases in which two neighboring car size classes were chosen and placed them on the scale between the respective classes. Through this process, 68.8% (326) of the new car buyers could be integrated.

Finally, several items measured the relevant socio-demographic variables of gender, age, education, number of persons in the household, and household income.

4.2 Sample characteristics

The resulting new car buyer sample contained 326 respondents with a mean age of 51.2 years (min. = 19, max. = 85, *S.D.* = 13.6) and 73.5% male respondents. With regard to education, 37.2% of the respondents received vocational or professional training, 8.8% acquired general qualification for university entrance, and 49% received a degree from a higher vocational, professional or academic educational institution.

The median monthly household income was EUR[1] 5001-6250 on a categorical scale. The average household size in our sample was 2.4 persons (*S.D.* = 1.1; number of adults: $M = 2.0$, *S.D.* = 0.8; number of children: $M = 0.4$, *S.D.* = 0.7).

Between the socio-demographic variables, significant positive correlations of a meaningful size ($r \geq .25$, $p \leq .001$, $N \geq 278$) were observed – as might be expected – for income and education as well as for income and number of persons in the household, both with a positive sign. With regard to gender, men ($M = 53.3$, $N = 235$) are significantly older than women ($M = 45.0$, $N = 83$; $p < .001$), live in larger households ($p < .05$) and have higher household income ($p < .01$). These effects may be explained mainly because in couple households, often the male partner filled out the questionnaire; among female respondents, single households are over-represented. To take these relationships as well as those with the other relevant variables into account, we included the socio-demographic variables in the statistical analyses.

The sample of this study should ideally be representative for the population of Swiss new car buyers. Analyses of the representativeness of the whole survey sample for the general population of Swiss car buyers showed that the survey sample contains considerably less one-person households and more higher-educated people. We assume that the reported deviations also exist for the subsample of new car buyers. However, due to a lack in information for the whole population, differences regarding income could not be analyzed.

1. Applied CHF/EUR exchange rate = 1.60

5 Survey results

5.1 Willingness to change purchase behavior for incentives

For the possible reactions to financial incentives, the mean values give a first impression of the sample's general degree of willingness to change behavior. The values generally range slightly below the scale mean of 3. Willingness to change to smaller engine (M = 2.9) was rated significantly higher than willingness to change both to a smaller (M = 2.7) and to a larger car (M = 2.6). However, it must be taken into account when interpreting these ratings that for questions measuring agreement, like willingness items, respondents usually show a tendency to agree rather than to disagree, independent from the content of the questions (Krosnick, 1999). This may lead to an overestimation of willingness to change behavior.

5.2 Acceptance of feebates

Compared to other energy reduction measures, the acceptance of feebates reached a medium level (see Table 2.2), with acceptance significantly higher for rebates than for fees.

Table 2.2. Item characteristics and factor loadings resulting from an exploratory factor analysis on items assessing acceptance of various measures conceivable for reducing energy consumption of road transport

Item	*M*	*S.D.*	Factor 1	Factor 2	Factor 3
Rise in fuel prices	2.0	1.3	.75		
Rise in fuel prices and refund	2.3	1.5	.81		
Rebate for highly efficient cars	3.4	1.5	.47		.44
Fee for highly inefficient cars	3.0	1.6	.65		
Information on problem of fuel usage	3.7	1.2		.81	
Information on economical cars	4.0	1.1		.83	
Regulations for manufacturers on consumption	4.0	1.2		.58	
Reduce rather usage of combustibles	3.2	1.3			.79
Measures abroad instead at home	2.4	1.3			.78
Explained variance of factor			21.30	20.02	17.24

Note. The numbers represent the loadings above .4 after factor rotation according to the Varimax criterion ($N \geq 304$).

Both received significantly better ratings than fuel price increases (even if such increases are refunded to the population through, for instance, health insurance) and energy reduction measures abroad. The only measures which scored significantly higher were information on efficient cars and supply-side regulations.

An exploratory factor analysis reveals three factors underlying the assessment and acceptance of various energy reduction measures (see Table 2.2). The first factor includes the monetary regulations affecting the consumers. The second factor summarizes measures that do not place constraints on consumers, such as simply providing information or passing regulations on manufacturers. The third factor relates to measures which intend to reduce energy consumption in areas other than the national transport sector.

5.3 Relating socio-demographics, preferred car size, and policy acceptance with willingness to react

Separate multiple regression analyses were conducted for each stated willingness to react (change to smaller engine/smaller car/larger car). Predictor variables were preferred car size class, acceptance of rebates, and socio-demographic variables (age; household income; gender; education; number of persons). A forward stepwise method was used: predictor variables enter the equation consecutively, ordered by their partial correlation with the willingness item (criterion for entry: $p = .05$; criterion for removal: $p = .10$). To reduce the risk of multi-collinearity, the analyses were computed in the first step only with the socio-demographic variables. During the process, estimation errors by multi-collinearity were controlled.

The regression analyses predicting the willingness to change from the subset of socio-demographic variables showed a significant negative contribution of household income for all three willingness variables. For the willingness to change to a larger car, a significant effect was also observed for household size, with a positive sign. In addition, the negative beta weight of the age variable was significant regarding willingness to change to a smaller engine. These results are generally in line with the assumptions described in Section 3. However, the squared multiple correlation obtained was small ($R^2 \leq .057$, adjusted $R^2 \leq .050$). The demographic variables that these analyses revealed as relevant were included in the next step of analysis.

The regression analyses on acceptance of rebates, preferred car size class, and the relevant socio-demographic variables (see Table 2.3) showed that

both acceptance and preferred car size significantly contributed to all three willingness variables. They appeared to be less important for changes to a larger car, but their contribution is still significant. The results are consistent with hypotheses 1 and 2. However, we did not expect preferred car size to contribute to the willingness to change to a larger car, especially as in this case respondents which already prefer larger cars state a slightly higher willingness.

Table 2.3. Significant standardized regression coefficients β and R^2 of regression analyses for variables predicting the different types of willingness to react

Predictor variables	**Willingness to change to**		
	... a smaller engine	**... a smaller car**	**... a larger car**
Acceptance of rebates	.436***	.381***	.243***
Preferred car size	-.263***	-.257***	.145*
Household income			-.203**
Household size (no. of persons)			.194**
R^2 (adjusted R^2)	.262 (.256)	.213 (.207)	.134 (.122)

Note. Stepwise selection of variables ($N \geq 274$).
*$p \leq .05$; **$p \leq .01$; ***$p \leq .001$.

Household income and household size have additional significant contribution only with regard to the willingness to change to a larger car, in which case they are more relevant than the preferred car size class.

6 Discussion and conclusion

The goal of this paper was to analyze whether absolute feebates (based strictly on energy consumption) or relative feebates (based on the ratio of energy consumption to car utility) encourage more consumers to change to vehicles with less energy consumption. We used curb weight to operationalize car utility and regarded feebate systems based on a discrete classification, with every vehicle being assigned to one of seven classes from A (highly efficient) to G (highly inefficient) where A-labeled vehicles are entitled to a rebate.

A basic assumption of this paper is that consumers change their purchase behavior due to rebates only within a limited range. If the step towards an A-labeled vehicle is too large, a buyer will not change his purchase behavior at all. Therefore, feebate systems should balance between keeping to the under-

lying policy target (energy consumption) on the one hand and trying to offer "relatively energy-efficient" cars to many buyers on the other hand.

In Section 2, we compared the effects of absolute and relative feebate designs on the number of A-labeled vehicles available, if at all, for the defined car size, engine size, and price segments. A relative design leads to more A-labeled vehicle availability for larger car and engine sizes and in higher price ranges. Thus, it succeeds better in offering A-labeled cars to buyers preferring larger cars.

For four different types of behavioral change induced by feebate systems (i.e., switching to A-labeled cars: (i) within the same utility segment; (ii) with smaller engine; (iii) with smaller car size; and (iv) with larger car size), we explored the possible effects on CO_2 emissions within the different designs of feebate schemes. By definition, an absolute system linked directly to the policy target (i.e., reduction of energy consumption and CO_2 emissions, respectively) does not encourage any changes increasing this target parameter. However, within a relative design, a significant proportion of the possible changes to A-labeled cars that are within range of minor behavioral changes are unsuccessful in reducing CO_2 emissions. Such changes leading to stagnating or increasing CO_2 emissions could occur with all four variants of behavioral change. In spite of this, none of the variants is a priori bad; even for the case of changes to a larger car size class, the total number of possible changes which reduce CO_2 emissions still prevails. This underlines the importance of studying the effects of these changes with a very disaggregated car fleet.

In the second part of this paper, we outlined the psychological mechanisms and factors decisive for consumers' willingness to change purchase behavior under feebate systems (Section 3) which was empirically investigated by a survey of Swiss households on car purchase behavior (Section 4). The results for the relevant sample of potential new car buyers were presented in Section 5. In general, the respondents showed some, but limited, willingness to change their car choice behavior in order to obtain a rebate. Upon deeper analysis, it was revealed that the potential new car buyers who preferred comparatively smaller cars exhibited higher willingness to reduce engine and car size. This is in line with our hypothesis. Contrary to a priori expectations, respondents with preference for larger cars tended to state higher willingness to change to even larger cars than those with preference for smaller cars.

There was a medium level of general acceptance of feebates among various other measures to reduce consumption of fuel and energy. Feebates

clearly ranked above rather unpopular measures such as increased fuel taxes. Only measures that do not require behavioral changes of consumers (e.g., provision of information on efficient cars, regulations for manufacturers) scored higher acceptance. We conclude that public acceptance for feebate systems is comparatively high.

In line with our hypotheses, acceptance of rebates contributed to willingness for all changes of behavior, although the contribution was clearly smaller for the change to larger cars. These results underline the importance of acceptance as well as its risks. The fact that people accept a scheme as reasonable and justified might not mean that they totally understand the mechanisms of the scheme in its specific design but rather that they accept both the necessity to reduce energy consumption as well as the applicability of feebates as a sensible tool for that aim. Consequently, results suggest that they are more willing to be influenced by the measure. In the case of a design opening the door to a counterproductive changing behavior, it is likely that people may take the incentive as a sign that buying the corresponding product follows the intended purpose of the feebate system without differentiating between changes to the "good" and changes to the "bad". If, however, they realize that changes countering the aims of the system could be rewarded, its acceptability could be endangered, which again endangers the scheme's effects as a whole.

The quantification of the presented insights and results with regard to the efficacy and efficiency of the various feebate designs is impossible within the scope of this work. With the current state of knowledge, we suppose that using a relative energy efficiency definition which normalizes the amount of energy needed by a surrogate for car utility might be a feasible option.

The consequences of using different parameters as policy targets or as surrogates for car utility are not assessed in this paper (see E.V.A., 1999; Boardman et al., 2000) but the principal dilemma is always the same and inherent to the problem which is outlined in the following.

If cars have a utility for consumers that correlates with energy consumption, not all consumer segments will be addressed by an absolute feebate system. In order to address more consumers, energy consumption needs to be normalized by a parameter operationalizing utility. Theoretically, this is achieved best by a parameter which perfectly corresponds to the vehicles' utility for the consumers.

In the choice of this parameter, one faces two problems: First, consumers are heterogeneous and differ in their concept of vehicle utility, such that a

compromise which is appropriate for as many consumers as possible would have to be found. Second, the dilemma inherent to the problem is that by normalizing energy consumption by a parameter representing consumers' utility, one opens the door to counteracting effects. Consumers might not stick to the parameter's value they would prefer without a rebate system but be willing to change to a vehicle with a higher value on this parameter especially if they are rewarded for this change by becoming eligible for a rebate.

The parameters which are feasible to operationalize car utility differ in the exact magnitude of undesired counteracting effects, because they correlate with CO_2 emissions to different degrees and they succeed differently in operationalizing the utility concepts of heterogeneous consumers. In order to find the optimal trade-off in this dilemma, micro-simulation with a highly detailed car fleet and differentiated consumer segments with their specific perception of "car utility" seems the most promising option.

Chapter III

Psychological factors that influence the choice of new vehicles with regard to fuel economy and CO_2 emissions

Abstract

The reduction of CO_2 emissions from road transport ultimatively means that buyers of new cars will have to switch to vehicles with better fuel economy. However, facing the ongoing trend of increasing car size and power, fuel consumption is apparently of lesser importance to most buyers. For the design of effective measures to change behavior and promote fuel efficient cars, psychological factors should be considered. Drawing from psychological research on environmental behavior, we propose a model which integrates hypothesized psychological determinants on rated CO_2 emissions of new cars bought by private consumers. This model is tested with survey data from 302 Swiss respondents whose households have bought a new car since 2002. SEM analyses confirm personal norm, valence of less power and smaller size, and perceived behavioral control as direct predictors of CO_2 emissions of the respondents' vehicles. Problem awareness, symbolic motives, and response efficacy influence the CO_2 emissions indirectly via affecting the direct predictors. The design, implementation and evaluation of policy measures aimed at changing car choice behavior with respect to fuel consumption should account for these factors.

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1 Introduction

Facing the global challenges of climate change and energy supply security, road transport plays a crucial role as one of the major energy consuming and CO_2 emitting sectors worldwide (IEA, 2006; IPCC, 2007a). Increasing fuel efficiency of new vehicles belongs to the most significant options to reduce energy consumption and CO_2 emissions in this sector. Besides technical solutions, a large potential for improvement in fuel efficiency persists in enhancing consumers' adoption of fuel-efficient cars (DeCicco, 2006).

Various policy measures are conceivable to increase the attractiveness of fuel-efficient vehicles, e.g., labeling of fuel-efficient vehicles (see, e.g., Teisl, Rubin, & Noblet, 2008) or monetary incentive schemes (see, e.g., Peters, Mueller, de Haan, & Scholz, 2008). For the choice and design of interventions, it is crucial to know which factors influence vehicle choice of consumers with regard to fuel consumption and CO_2 emissions.

Such vehicles need not necessarily be small vehicles or vehicles with new technology, e.g., with hybrid power trains. Even within vehicle models with conventional technology (gasoline and diesel engines), large differences in efficiency exist. For example, for the 15 most-sold passenger car models in Switzerland in 2006, a change from the least efficient version to the most efficient version would mean on average a reduction of 40.3% of CO_2 emissions (94 g CO_2/km) (de Haan, Mueller, & Scholz, 2009). Hence, effective pro-environmental purchase behavior could already be if people change to less fuel consuming and, thus, less CO_2 emitting vehicles within their preferred car size class, i.e., to vehicles which – in relationship to their size – consume less and which are thus fuel-efficient. In this paper, we will use the term "more fuel economical vehicles" to address the idea of fuel efficiency as comparative fuel economy related to other functional vehicle parameters such as size or weight of a vehicle (cf. Peters, Mueller, de Haan, & Scholz, 2008). Throughout this paper, a "more fuel economical vehicle" designates a vehicle that uses less fuel to drive a given distance than other cars which are comparable with respect to functional vehicle parameters, such as vehicle size, number of seats, or luggage capacity.

Public attention for the complex global problems related to energy consumption of vehicles has been rising: People have begun to be alert to climate change (cf. Anable, Lane, & Kelay, 2006) and attach great importance to the challenges of energy supply and reduction of CO_2 emissions (e.g., Kuckartz, 2006). Surveys reveal that consumers are to some extent aware

that car traffic contributes to these problems (e.g., Anable et al., 2006; Lane & Potter; 2007; Nordlund & Garvill, 2003). However, when purchasing a car, environmental issues such as fuel consumption and CO_2 emissions still have a low priority (Anable et al., 2006; Lane & Potter, 2007). Zachariadis (2006) points out that greater reductions in fuel consumption, rendered possible through improved technologies, would have been achieved if consumers had not shown their preferences for bigger, faster and, supposedly, safer cars. Average vehicle weight, engine capacity, and power have constantly increased in the past, partly due to dieselization as well (Zachariadis, 2006; cf. also ACEA, 2007). In Switzerland, where we conducted this study, passenger cars are, on average, even heavier and have more engine capacity than those in the rest of Western Europe (see Figure 3.1 and Figure 3.2). This might be due to the high Swiss gross domestic product per capita. Nevertheless, the general trend is the same.

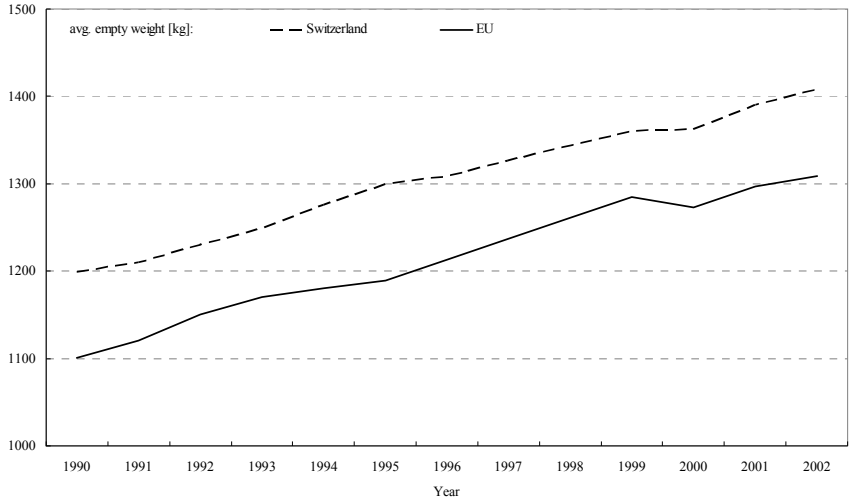


Figure 3.1. Evolution of average empty weight (in kg) of new passenger car registrations in Switzerland and the EU. Data source: auto-schweiz, 2007; Zachariadis, 2006.

So, how can we explain the low rate of consumers' adoption of more fuel economical vehicles? Research has shown that besides concern or so-called problem awareness various specific beliefs, attitudes, norms, and motives influence most cases of environmental behaviors (Bamberg & Möser, 2007). Bamberg, Hunecke, and Blöbaum (2007) point out the need for theoretical

frameworks that allow an understanding of the relative importance and interaction of different factors influencing people's decisions in the context of a specific behavior.

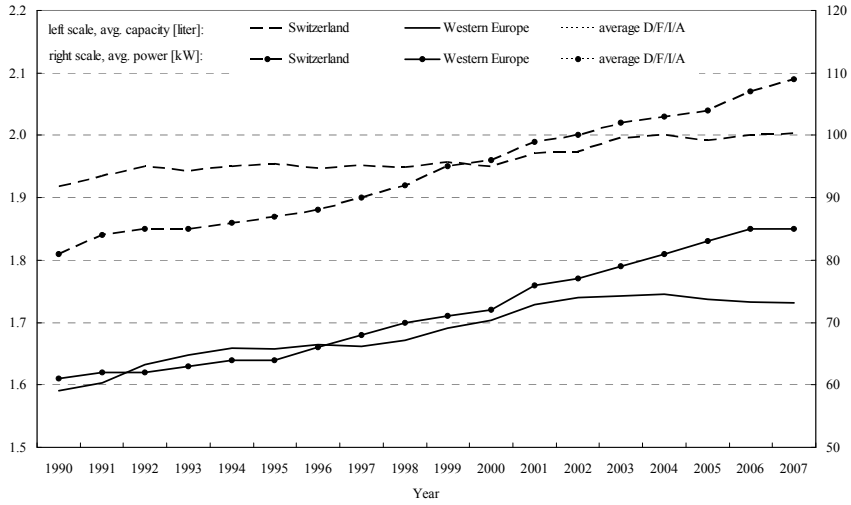


Figure 3.2. Evolution of average engine capacity (in litres; left scale) and power (kW; right scale) of new passenger car registrations in Switzerland, Western Europe, and Switzerland's neighboring countries D/F/I/A (weighted by car sales). Data source: ACEA, 2007.

Regarding the topic of car purchase, published studies which integrate a pool of variables derived from psychological theory are rare (without doubt, a lot of proprietary research on the role of psychological factors within vehicle choice exists). Published models to forecast car buying behavior have been developed mainly by economists and market researchers aiming to forecast the choice of vehicle type or model in order to estimate market shares (Choo & Mokhtarian, 2004). However, these models have differentiated consumers primarily by their socio-demographic characteristics which are used to explain the weighting of the included vehicle attributes. The incorporation of psychological factors is a rather new approach not only in specific modeling of car choice but in general choice modeling as well (Ben-Akiva et al., 1999; Choo & Mokhtarian, 2004). With regard to vehicle type choice, Choo and Mokhtarian (2004) showed that the inclusion of psychological constructs such as attitudes, personality, and lifestyle contributes substantially to the predictive power. Their work points out a way to further improve vehicle choice models with regard to prediction and policy analysis.

However, as outlined above, additional work, based on psychological theories, is necessary to identify which variables exactly to include in the case of vehicle purchase behavior. In general, drawing from psychological research on environmental behavior, the aim of the current paper is to identify the relevant subset of psychological variables influencing the purchase of new cars with regard to fuel consumption and CO_2 emissions which are directly linked to each other. After a short overview on some theoretical psychological approaches and findings relevant for this study, we propose a model of various psychological determinants for explaining rated CO_2 emissions of newly bought cars.

2 Factors influencing environmental behavior

In this section, we will first outline general research on environmental behavior in order to derive a theoretical framework which integrates different determinants of environmental behavior. We define environmental behavior as behavior that is relevant for the environment in that it can be environmentally sound or harmful to varying extent (cf. Homburg & Matthies, 1998; Stern, 2000). Subsequently, we will focus on the specific case of car purchase and its characteristics and relate the framework to empirical findings relevant for environmental behavior in this field. Finally, we will present the theoretical model of this study.

2.1 A theoretical framework of environmental behavior

Over the last decades many studies have been conducted to investigate the determinants of different environmental behaviors. Wall, Devine-Wright, and Mill (2007) point out that in order to develop a coherent theory of environmental behavior and cumulate understanding, research building on proven theories seems reasonable. Hence, in this paper, we will concentrate on studies based on the theories most applied. These are the theory of planned behavior (TPB, Ajzen, 1991) and the norm-activation model (NAM, Schwartz, 1977; cf. Bamberg & Möser, 2007; Matthies, 2005). According to the TPB, behavior is immediately influenced by a person's intention to perform the behavior. Intention, in turn, is determined by (1) a person's attitude towards the behavior, defined as an overall evaluation of its possible consequences, (2) subjective norms, referring to the perceived expectations

of other important persons (we will speak of social norms in the following), and (3) the perceived behavioral control (PBC), defined as a person's perceived power to perform the behavior due to non-motivational factors as availability of opportunities and resources. Besides the indirect influence of PBC on behavior via intention, a direct one can also be assumed to the extent that the person perceives her objective power to perform the behavior accurately. The development of attitude as an overall evaluation of the behavior is conceptualized by Ajzen (1991) as expectancy-value model. According to this model, the expectancy that a behavior results in particular consequences and the evaluation, i.e., the valence of these consequences, are assumed to underlie the overall evaluation of the behavior.

Studies using the NAM explain environmental behavior as being influenced by (1) a personal ecological norm, denoting a strong intrinsic feeling of obligation to engage in the specific pro-environmental behavior. This personal norm is formed and activated by (2) the awareness of an environmental problem and by (3) the awareness of environmental consequences of one's own behavior, denoting the perception that one's own behavior has harmful consequences for the environment and that, thus, a change of behavior has an effect on the problem[2]. As we are especially interested in this last aspect of perceiving that one's own behavior can make a difference and as we focus the operationalization of this construct on this dimension, we prefer the term response efficacy which will be used in the following.

For both theoretical frameworks, a lot of empirical evidence has been collected for a variety of environmental behaviors (for the TPB, e.g., Haustein & Hunecke, 2007; Kaiser & Gutscher, 2003; Kalafatis, Pollard, East, & Tsogas, 1999; Tonglet, Phillips, & Read, 2004; for the NAM, e.g., Gärling, Fujii, Gärling, & Jakobsson, 2003; Hopper & Nielsen, 1991; Hunecke, Blöbaum, Matthies, & Höger; 2001; Thøgersen, 1999).

Generally, they have been interpreted as reflecting two different, contrasting view points: environmental behavior as rational and self-interested behavior vs. as pro-social behavior (cf. Bamberg & Möser, 2007; Homburg & Matthies, 1998). We do not want to discuss this complex topic in detail.

2. Bamberg and Möser (2007) use the term "internal attribution". In general, the meaning of this construct relating to the awareness that the own behavior has an effect and, hence, can make a difference has appeared in literature under different labels, e.g., as efficacy (e.g., Kerr, 1992), response efficacy (e.g., Lam & Chen, 2006), or perceived (consumer) effectiveness (e.g., Thøgersen & Ölander, 2006). However, it has to be distinguished from concepts which relate to judgments of how well one can execute the behavior in question (e.g., Ajzen's (1991) concept of perceived behavioral control; Bandura's (1977) concept of perceived self efficacy).

However, the reader should keep in mind that the variables of the TPB might also be influenced by concern for other people, other species, and the environment as a whole. Thus, Bamberg and Schmidt (2003) showed that environmental concern has substantive influence on the perception and evaluation of situation-specific cognitions, conceptualized via Ajzen's TPB. Nevertheless, we agree with the abovementioned interpretation regarding the point that an explicit pro-social motivation of behavior is neglected by the mere application of the TPB and that hypotheses about its interplay with the other TPB variables are not included.

In order to better account for the role of the various determinants proven to influence environmental behavior and in order to understand the underlying preconditions and processes, a promising trend of the last decade is to combine both theoretical frameworks (cf., e.g., Bamberg & Möser, 2007; Homburg & Matthies, 1998). In this regard, the most comprehensive study, to our knowledge, was conducted by Bamberg and Möser (2007). Their proposed structural model integrating the TPB and the NAM was confirmed by a meta-analysis based on 46 studies applying the TPB, NAM or similar models to environmental behavior. However, the relations of the model variables depend considerably on the type of behavior or the kind of sample analyzed in the primary studies.

2.2 The case of car purchase behavior

With regard to the area of environmental purchase behavior, Wiese, Sauer, and Rüttinger (2004) showed for the case of household appliances that product-specific characteristics influence consumers' consideration of environmental aspects. The purchase of vehicles may be special when compared to the purchase of other products with regard to the following characteristics. Vehicles do not belong to everyday consumption and can be regarded as major investments. The high observability of this product class as well as emotions associated with cars contribute to the high involvement of many consumers. Abramson and Desai (1993) even coin the term "ultra-involvement" to address the continuous attention of many people to communication and information about certain product categories such as cars. In the actual purchase situation, a lot of information may be blocked out or regarded unworthy of evaluation, e.g., when strong beliefs and attitudes exist. This is in line with the concept of bounded rationality (Simon, 1957; see also Gigerenzer, Todd, & the ABC Research Group, 1999): confronted with a vast num-

ber of potential alternatives and many decision attributes, decision makers have to simplify the decision situation and to focus on certain aspects and neglect others.

Various studies indicate several factors impeding the consideration of fuel consumption in this situation. In the following, we will briefly discuss these findings, relating them to the constructs of the integrated theoretical framework presented above.

With regard to *problem awareness*, research indicates that many people have become aware of the problems of climate change and energy supply (Kuckartz, 2006; cf. Anable et al., 2006) and relate them to some extent to car use (e.g., Lane & Potter, 2007; Nordlund & Garvill, 2003). However, there is evidence that detailed understanding of climate change and of the relationship between fuel use of vehicles and their CO_2 emissions is very low among consumers (Anable et al., 2006; Lane & Potter, 2007; DeCicco, 2006). From a review of research on attitudes and behavior relevant for climate change, Patchen (2006) concludes that people have only vague or mistaken ideas about the most appropriate solutions to mitigate climate change (cf. also Boardman, Banks, Kirby, with Keay-Bright, Hutton, & Stradling, 2000). This addresses *response efficacy* of one's own behavior as an influencing factor. DeCicco (2006) notes that, even if consumers are aware of the environmental consequences of fuel use, they do not seem to connect them to their own decisions and behavior. Denial of responsibility and justification by the relative insignificance of one's own behavior seem to play a role here (cf., e.g., Stoll-Kleemann, O'Riordan, & Jaeger, 2001).

Concerning *attitude* towards buying a more fuel economical vehicle, a study of Klocke (2002a) indicates its influence on the purchase of such vehicles. It is thus informative to examine the *underlying specific beliefs* about the consequences of buying such vehicles (cf. Ajzen, 2007). A survey by Turrentine and Kurani (2007) indicates that most consumers associate fuel economy with the smallest and cheapest vehicles. With regard to the understanding of fuel efficiency (cf. Section 1), their study suggests that many consumers do not perceive any difference between fuel economy and fuel efficiency. Those respondents for whom the two terms mean different things associate fuel efficiency – in contrast to fuel economy – with higher quality vehicles and new technology (Turrentine & Kurani, 2007). These associations, in turn, might foster the expectation that more fuel economical vehicles may be more expensive than vehicles which are less fuel economical. Apparently, consumers assume fuel consumption to vary only marginally

within one vehicle size class and conventional technology range (cf. Boardman et al., 2000). Thus, the perception that the only way to have a more fuel economical vehicle is a trade-off against size, performance, comfort, and safety (cf. also Kurani & Turrentine, 2004) might stabilize the disregard of fuel consumption in the purchase process. Even environmentally oriented car buyers are not less discerning for classic product attributes, such as safety, and seem to accept cutbacks only on specific attributes (Brocke, Holling, & Thoring, 2004).

These findings also have implications for the construct of *perceived behavioral control (PBC)*: On the one hand, associations of more fuel economical vehicles with small size and poor value might foster the belief that more fuel economical vehicles which are appropriate for one's needs are not available. On the other hand, if consumers relate more fuel economical vehicles to new technology and high quality, they might perceive them as too expensive. Thus, these associations indicate subjective barriers which reduce PBC.

Also, the relevance of *social norms* for the intention of buying a more fuel economical vehicle has been suggested in Klocke's study (2002a). An influence on the purchase itself was not observed. However, to our knowledge, no other study on social norms in environmental car purchase exists, and even no research addresses the role of personal norms within this topic.

In contrast, in the field of car use and travel mode choice, social norms as well as personal norms in favor of environmental mode choice have qualified as predictors of behavior in various studies (social norm: e.g., Bamberg et al., 2007; Haustein & Hunecke, 2007; Hunecke et al., 2001; personal norm: e.g., Bamberg et al., 2007; Hunecke et al., 2001; Matthies, Klöckner, & Preißner, 2006).

This empirical outline underlines the importance of the various framework constructs. However, for the specific case of car purchase, we may have neglected another important determinant thus far. Research on motivational factors of car use has shown that symbolic and affective motives play an important role for car use besides instrumental ones (Steg, 2005). A motive is a relatively stable trait which describes how important a person values a particular type of goals (Heckhausen, 1989). Thus, it is reasonable to assume that motives influence the evaluation of certain consequences of behavior, i.e., the attitude towards a behavior.

Material possessions like cars fulfill an important symbolic function in the expression of one's self and of one's social position or group membership (Dittmar, 1992). Accordingly, the strength of a person's symbolic motives in-

fluence how much importance or value she attaches to vehicle criteria such as car size and power or other criteria which can fulfill a symbolic function, i.e., a function to express identity.

Her instrumental motives influence how she evaluates the convenience of a specific vehicle with regard to, e.g., luggage capacity, number of seats, and safety. Finally, the strength of her affective motives determine if emotions, e.g., feelings of enjoyment or excitement which are related to specific car types or brands play a role in her choice of a vehicle (cf. Steg, 2005). However, in this study we do not include affective motives.

The influence of symbolic motives on vehicle choice is also indicated in a study of Choo and Mokhtarian (2004) who found drivers of luxury cars to be overrepresented among groups with high education and higher income and to be associated with a status-seeking lifestyle. In public, status still seems to be considerably connected to vehicle size and performance. However, a study by Turrentine and Kurani (2007) indicates that fuel economy can be a symbolic feature as well if car drivers view resource conservation as important values.

Steg (2005) points out that applications of the theory of planned behavior typically focus instrumental motives via the evaluations of consequences which they influence and which are studied as being relevant for the attitude. With regard to car choice, e.g., people can evaluate a smaller size as negative due to their instrumental motives. However, these evaluations and thus, the general attitude, are also influenced by a person's symbolic motives. Thus, she could also evaluate a smaller size as negative if she wants to express a certain social position by her vehicle.

In order to identify an influence of symbolic motives on the evaluation of consequences of a purchase of more fuel economical vehicles, we include symbolic motives as distinct construct. Further, it will be important that among the consequences to be evaluated both instrumental aspects and symbolic aspects are well represented.

Also with regard to the activation of a personal norm to buy a more fuel economical vehicle within the decision process, it seems reasonable that symbolic motives influence this activation, depending on the vehicle characteristics which have symbolic function for a person.

With regard to financial aspects influencing the purchase of more fuel economic vehicles, we want to point out that on the one hand, an association of higher purchase prices with such vehicles may represent a relevant barrier for the behavior in question. On the other hand, saving money on gasoline

could be a financial incentive to purchase a more fuel economical vehicle. Economic assumptions that consumers rationally consider fuel consumption in their car use and purchase decisions with regard to the costs of gasoline over time have often been underlying studies to analyze, for example, the effect of rising gasoline prices (Kurani & Turrentine, 2004). In contrast, interviews conducted with automobile buyers reveal that consumers of all types miss the basic knowledge for such rational decision-making and value fuel economy not only because of cost savings (Turrentine & Kurani, 2007). Consumers of hybrid vehicles, for example, who pay for new technology to improve fuel economy proved to be less interested in saving money than in environmental issues addressed by their vehicle. This finding was also underlined by the knowledge differences regarding these two issues. Hence, we do not broaden our framework by the motivation to save costs over time and concentrate our study on the variables outlined above.

2.3 The theoretical framework with regard to environmental car purchase behavior

Based on the theoretical and empirical outline presented above, in this section, we transfer the general theoretical framework (cf. Section 2.1) to the case of environmental car purchase. The specific model to explain the CO_2 emissions of new vehicles is depicted in Figure 3.3.

Corresponding to the TPB, the attitude towards more fuel economical vehicles and the perceived behavioral control with regard to the purchase of a more fuel economical vehicle are conceptualized as predictors of the CO_2 emissions of new vehicles. As suggested by Bamberg and Möser (2007), personal norm takes the role of TPB's third predictor social norm which receives a more indirect role of influence via affecting personal norm, attitude, and PBC. The underlying assumption is that social norms exert influence less for the fact that they signalize social pressure for "wrong" behavior, but rather because they are informative with regard to the moral or normative appropriateness of a behavior, its benefits, and difficulties in performing it. This corresponds to Schwartz' (1977) definition of personal norms as internalized social norms, experienced as a feeling of moral obligation with regard to specific action in a particular situation. Studies incorporating social as well as personal norm (e.g., Matthies et al., 2006; Harland, Staats, & Wilke, 1999; Wall et al., 2007) support the assumed theoretical structure by indicating that

social norm often exerts no direct effect on intention after checking for the effects of personal norm.

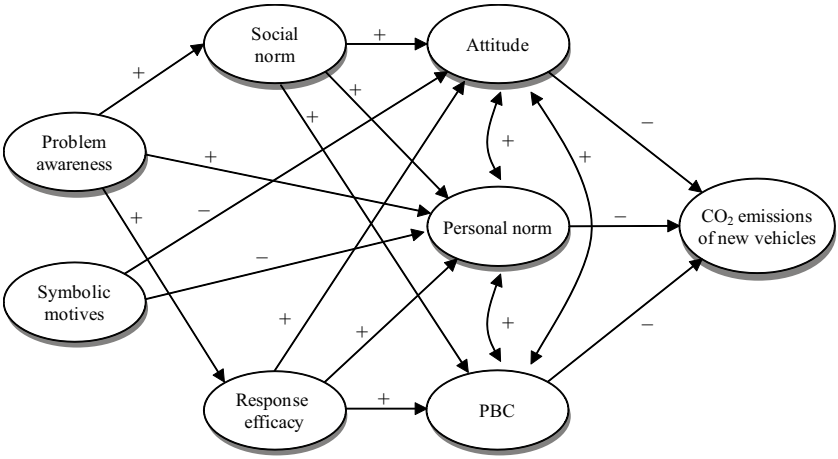


Figure 3.3. Theoretical integrated model to explain CO_2 emissions of new vehicles, adapted from Bamberg and Möser (2007), enriched with symbolic motives. "+" indicates positive influence, "-" indicates negative influence.

According to the meta-analysis of Bamberg and Möser (2007), PBC, attitude, and personal norm correlate with each other only moderately, which confirms their empirical independence. In line with the NAM, the awareness of ecological problems related to vehicle use and the response efficacy of one's own vehicle purchase with regard to these problems are assumed as preconditions of the personal norm to buy a more fuel economical vehicle.

As a new component beside the TPB and NAM components, we added symbolic motives to account for the special characteristics of vehicles. We suppose that at the time of this study, traditional symbolic vehicle characteristics such as vehicle size and performance are still of considerable symbolic value in contrast to fuel economy and low CO_2 emissions, although this may be changing. According to the above presented outline, we assume that symbolic motives, i.e., motives to express one's self and one's social position, exert an indirect positive influence on CO_2 emissions of new vehicles mediated by the predictors personal norm and attitude towards more fuel economical vehicles which are negatively influenced by symbolic motives. Thus, strong symbolic motives to express one's personality and social status with one's own car may inhibit the activation of a personal ecological norm to purchase a more fuel economical vehicle. As well, strong symbolic motives may influ-

ence the perception and evaluation of possible consequences associated with buying a more fuel economical vehicle which determine the general attitude towards this behavior.

Based on this model, we want to study the determinants of the purchase of vehicles which emit less CO_2.

Our hypotheses are the following:

H1: PBC, attitude, and personal norm have a negative direct influence on the CO_2 emissions of new vehicles.

H2: Problem awareness, response efficacy, and social norm have a negative indirect influence on the CO_2 emissions of new vehicles which is mediated according to the paths in Figure 3.3.

H3: Symbolic motives have a direct negative influence on personal norm and attitude and, thus, an indirect positive influence on the CO_2 emissions of new vehicles.

H4: PBC, attitude, and personal norm correlate with each other (as independent predictors).

Finally, more exploratively, we want to analyze the consequences people associate with the purchase of more fuel economical vehicles, i.e., the expected characteristics of more fuel economical vehicles and people's evaluation of these characteristics.

3 Method

3.1 Participants

We only regard respondents whose households have bought a new vehicle since 2002. The corresponding data set for this study consists of 302 respondents and results from the following sampling procedure within a two-wave study. The first questionnaire was sent out in June 2005 to 5890 households in the German- and French-speaking part of Switzerland randomly chosen from the phone book. From 2333 respondents (response rate = 39.61%), 1545 (66.22%) were both willing to participate again and still reachable under their address. Of these, 1150 (response rate = 74.43%) returned the second questionnaire which was sent out one year later in June 2006.

Compared to those who filled out both questionnaires, the respondents who dropped out after the first questionnaire differ with regard to several

characteristics. Female respondents, respondents living in smaller households, with lower household incomes and with a lower educational level were overrepresented among the drop-outs. No differences were observed on the age variable. As to be expected due to the even stronger focus on car purchase in the second questionnaire, also respondents whose household possess no car or who could not at all imagine buying a car within the next 10 years dropped out above average.

Of the 1150 respondents of both questionnaires, 359 (31.22%) had bought a new car since 2002. From this sample, the following records were excluded: (1) records with 50% of missing data or more for a multi-item predictor; (2) records for which technical data could not be assigned with satisfying quality for the vehicle (or vehicles) bought since 2002; (3) cases in which the first and the second questionnaire were not filled out by the same household member.

The resulting sample of $N = 302$ respondents contains 79% male respondents. For the time of the first survey in 2005, the mean age was 50.04 years (min. = 18, max. = 82, *S.D.* = 13.85), the median monthly household income was EUR[3] 5351-6650 on a categorical scale, the average household size was 2.65 persons (*S.D.* = 1.18; number of adults: $M = 2.06$, *S.D.* = 0.68; number of children: $M = 0.60$, *S.D.* = 0.95), and the average number of vehicles owned by a household was 1.62 (*S.D.* = 0.69).

Though for model testing, representativity of the sample is not a central requirement, this sample should ideally be representative for the population of Swiss new car buyers. Analyses of the representativeness of the whole survey sample for the general population of Swiss car buyers reveal that single households are underrepresented and that higher education households are overrepresented. Due to a lack of information on the income distribution for the whole population, differences regarding income could not be analyzed; however, due to the empirical education-income-correlation, we also suppose that the sample contains more households with higher income than the underlying population of Swiss car buyers. With regard to the sub-sample of new car buyers, we assume that the reported deviations are transferable.

3. Applied CHF/EUR exchange rate = 1.50

3.2 Vehicles

When households had bought more than one new vehicle since 2002, the youngest vehicle – according to its model year (vintage) – with data of satisfying quality was selected. Due to technological progress, average CO_2 emissions of European new car registrations have constantly decreased in the last 10 years by approximately 1% per year. Thus, new car registrations in Switzerland on average had 197.5 g CO_2/km in 2002, which dropped to 187 in 2006 (auto-schweiz, 2003, 2007). In order to compare CO_2 emissions of vehicles which were bought in different years – in analogy to the well-known inflation correction of prices – we normalize CO_2 emissions relative to the market average of 2006, by assuming annual efficiency increases of 1.20% and 1.60% for gasoline and diesel engines, respectively.

3.3 Survey procedure and measures

In this section, the modules and items of the survey which are relevant for this study are shortly described.

3.3.1 First questionnaire

CO_2 emissions of vehicles in possession. The respondents were asked to give detailed data on all cars currently owned by their household such as brand, model, fuel type, engine capacity, gear type, year of purchase, and model year (vintage). These data allow for a precise identification of any vehicle in the Swiss data base on vehicle type registrations and provide further technical characteristics including size, weight, fuel consumption, and CO_2 emissions of the vehicle.

Socio-demographic variables. Moreover, the first questionnaire included questions for socio-demographic variables of the respondent and household characteristics such as gender, age, education, number of persons in the household, and household income.

3.3.2 Second questionnaire

Gender and age were also assessed in the second survey wave to check that the same person has filled out both waves.

CO_2 emissions of vehicles in possession. The questionnaire for the second wave included a module which asked for meanwhile changes in the house-

hold's vehicle stock, i.e., whether the former owned vehicles are still in possession, whether new cars have been purchased and if yes, again for detailed data on the new vehicles.

Psychological constructs. The indicators that should measure the relevant constructs to explain the CO_2 emissions of the vehicles in question were included in the second questionnaire. Every construct was measured by several items which were formulated specifically to the topic of road transport and the problems of climate change and oil consumption. The items were based on Ajzen's (2007) general recommendations and on previous studies of environmental behavior (e.g., Hunecke et al., 2001; Steg, 2005; Scholl & Sydow, 2002); in a few cases the exact wording was adopted while most of the items were modified to different degrees. For the wording of the items, we decided not to use the term "fuel-efficient" vehicles but to circumscribe these vehicles as "more fuel economical" (as done in this paper). Unless otherwise stated, respondents rated their agreement on a 5-point response scale ranging from 1 (= not at all the case) to 5 (= very much the case). Negatively formulated items were reversed in coding.

Before presenting the items related to the environmental consequences of car use in the questionnaire, 6 items were used to assess the respondents' symbolic motives connected to car purchase and use. Awareness of climatic and resource problems related to road transport was assessed by 6 items. As well, a set of 6 items served to measure response efficacy and 5 items to measure perceived behavioral control. Personal norm was assessed by 3 items. With regard to the operationalization of social norms, Ajzen (2007) differentiates between injunctive and descriptive social norms. The injunctive norm describes whether most or, at least, important others approve or disapprove the behavior in question, whereas the descriptive norm describes whether they themselves perform this specific behavior. Often, these norm concepts may be consistent in that approved behavior is typical behavior. However, in cases of generally desirable behavior like environmental behavior, items to measure injunctive norms may have a low variability as important others are generally perceived to approve of desirable behaviors. In such cases, descriptive norms could be more indicative for the relevant influence of important others (cf. Ajzen, 2007). Hence, of 3 items to measure social norm 2 were formulated in terms of an injunctive norm and 1 item in terms of a descriptive norm.

Table 3.1. Wording, means, and standard deviations (S.D.) of the items included in the questionnaire to operationalize the latent variables (except attitude and the behavior) and corresponding reliability coefficients (Cronbach's alpha) (N = 302)

Latent variable (Cronbach's alpha) and associated indicators	***M***	***S.D.***
Social norm (α = .65)		
1. Most people who are important for me expect me to drive a car with the least possible fuel consumption (or no car at all).	2.04	1.10
2. Most people who are important for me drive more fuel economical cars or would drive such cars.	2.47	1.06
3. My familiy supports me in buying a vehicle with lower fuel consumption.	3.42	1.26
Perceived behavioral control (PBC) (α = .59)		
1. In my current life situation, I do not have the opportunity to take care for a lower fuel consumption when buying a vehicle. (recoded)	4.26	1.01
2. It is difficult for me to evaluate whether a car has a lower fuel consumption. (recoded)	4.21	1.05
3. I know where to get the information which are necessary to choose a more fuel economical car.	4.20	1.05
4. The purchase price of vehicles with a lower fuel consumption prevents me from buying such a vehicle. (recoded)	3.72	1.21
5. Currently, there is no car which is more fuel economical appropriate for me. (recoded)	3.47	1.36
Personal norm (α = .69)		
1. No matter, what other people do, I think it is the right thing to choose a car with a fuel consumption as low as possible.	4.13	0.91
2. The purchase of a vehicle with a rather high fuel consumption does not gnaw at my conscience. (recoded)	3.86	1.17
3. When making a trip by car, it should burden climate and oil reserves as little as possible.	4.15	0.82
Response efficacy (α = .81)		
1. If one depends on a vehicle, there are hardly any opportunities to do something for the protection of the climate in this domain. (recoded)	3.68	1.10
2. If one depends on a vehicle, there are hardly any opportunities to save oil in this domain. (recoded)	3.69	1.21
3. Buying a more fuel economical vehicle, I can effectively contribute to the protection of the climate.	4.18	0.89
4. Buying a more fuel economical vehicle, I can effectively contribute to save oil.	4.18	0.89
5. It doesn't matter what car I buy as it makes no difference regarding protecting our climate. (recoded)	4.16	1.04
6. It doesn't matter what car I buy as it makes no difference regarding oil reserves. (recoded)	4.06	1.03
Problem awareness (α = .81)		
1. People exaggerate the role of car traffic as the cause for climate change. (recoded)	3.38	1.15
2. The change of the climate should not be dramatized. (recoded)	3.73	1.09
3. People exaggerate the role of car traffic for oil consumption. (recoded)	3.62	1.04
4. When thinking of the consequences of traffic on the climate, I am very worried.	3.29	1.10
5. When thinking of how we deal with our oil supplies, I am very worried.	3.57	1.10
6. I don't believe that oil depletion is as bad as often claimed. (recoded)	3.60	1.04
Symbolic motives (α = .75)		
1. It is important to me to drive a car which appeals to me.	3.79	1.13
2. My car should suit me.	3.49	1.27
3. For me, the car has instrumental functions only. (recoded)	2.82	1.28
4. I want to drive a car which is not driven by everybody.	1.89	1.28
5. To me, cars are very important.	3.47	1.07
6. It does not matter to me which type of car I drive. (recoded)	3.75	1.22

The wordings of all these items are presented in Table 3.1. The items which finally constitute the confirmed indicators of the final measurement models are displayed in Table 3.4.

Finally, the general attitude towards more fuel economical cars was assessed, as well as underlying beliefs about characteristics of more fuel economical vehicles, i.e., expectancy and valence (cf. Ajzen, 2007). For the general attitude measure, subjects were asked to rate their general attitude towards more fuel economical vehicles (1 = very negative; 5 = very positive).

In order to explore which characteristics the respondents associate with more fuel economical vehicles, respondents should assess a set of 12 associations (presented in Table 3.2) on how much they correspond to their image of such cars (expectancy rating). These items were intended to exploratorily reveal the salient consequences of a purchase of more fuel economical vehicles as we did not explore them before the survey. Subsequently, respondents were asked to assess how negative vs. positive they would rate these criteria within car purchase (1 = very negative; 5 = very positive) to measure the valence of these conceivable characteristics of more fuel economical vehicles.

3.4 Analyses

For the multivariate data analysis, the structural equation approach was used (AMOS 6.0). First, the measurement models of the latent variables social norm, PBC, personal norm, response efficacy, problem awareness, and symbolic motives were specified.

In order to analyze the characteristics which the respondents associate with more fuel economical vehicles and to include an exploratorily derived attitudinal measure into the SEM model, the expectancy and valence measures were examined by means of their descriptives and an exploratory factor analysis using the products of multiplying the respective expectancy and valence ratings. Based on the results and theoretical assumptions, we included three indicators for the latent attitude variable into the measurement model.

The measurement models were tested via confirmatory factor analysis (CFA). Based on the results, several items were excluded. For all of the constructs, unidimensionality could be confirmed.

For the SEM analyses, we applied generalized least squares estimation because the assumptions of normal distribution for most of the model variables were violated. The final model which we suggest was achieved after some modifications to the theoretical model based on modification indices

and theoretical assumptions. These modifications will be described with the results. Moreover, non-significant paths which did not prove to have any significant direct or indirect influence on the main dependent variable were deleted from the final model.

4 Results

4.1 Descriptive results for the latent constructs

Latent constructs. Table 3.1 presents the wording, means, standard deviations, and reliability coefficients (Cronbach's alpha) of the items included in the questionnaire to assess the latent constructs (except for the dependent variable CO_2 emissions of new vehicles and the attitudinal predictor) as described above.

The items measuring personal norm and response efficacy as well as PBC reach considerably high mean scores. The problem awareness items are still slightly above the neutral range of the response scale, as well as most of the items assessing symbolic motives. However, the items measuring the social norm to buy more fuel economical vehicles expressed by the perceived expectations as well as perceived behavior of important others is rather weak (except the social norm within the respondent's family). In general, the size of the standard deviations of all items is moderate.

Attitudinal ratings. With regard to characteristics associated with more fuel economical vehicles, Table 3.2 depicts the means and standard deviations of the expectancy and valence ratings. The expectancy ratings show how much the respondents expect more fuel economical vehicles to have the respective characteristic (1 = very low expectancy, 5 = very high expectancy). The valence ratings show how the respondents would evaluate the respective consequence when associated with a vehicle they consider buying (1 = very negative, 5 = very positive).

As the figures for the valence ratings show, the mean values of respondents' evaluation of cars with less power, slower acceleration, and smaller size range slightly below the scale mean of 3. A boring image, a higher purchase price, and less comfort received rather negative ratings. Decreased safety was the vehicle characteristic which was rated most negatively. In contrast, fuel saving through new technology, environmental soundness as well as new fuel types received the most positive ratings.

For most of the items, the standard deviations indicate individual differences between the respondents which are a necessary prerequisite of predictive power of variables. Only, the ratings regarding the characteristics fuel saving through new technology and environmental soundness indicate high agreement between the respondents.

Table 3.2. Description of expectancy and valence for conceivable characteristics of more fuel economical vehicles (N ≥ 298)

Conceivable characteristics of more fuel economical vehicles	*M* expectancy	*S.D.* expectancy	*M* valence	*S.D.* valence
cars with a less powerful engine	3.49	1.23	2.75	0.94
smaller cars	3.42	1.22	2.91	0.96
cars which accelerate less than other cars	3.10	1.19	2.67	0.89
cars with a boring image	1.88	1.09	2.10	0.91
cars which save fuel through new technology	4.53	0.77	4.57	0.67
cars which are environmentally sound	4.34	0.78	4.52	0.68
cars which use a new fueltype	4.04	1.10	4.16	0.91
cars which are more expensive than other cars	2.98	1.27	2.23	0.93
cars which provide less safety than other cars	1.64	0.95	1.50	0.85
cars which are less comfortable	1.83	1.03	2.11	0.89
attractive cars	2.74	1.09	3.71	1.05
cars which have a pioneer image	3.22	1.31	3.48	1.09

Note. Item wording for the expectancy items: "When thinking of more fuel economical vehicles, I think of …"; response scale: 1 = not at all the case (very low expectancy); 5 = very much the case (very high expectancy). Item wording for the valence items: "Within car purchase, how do you evaluate …"; response scale: 1 = very negative; 5 = very positive.

However, which of these characteristics do the respondents mainly associate with more fuel economical vehicles? The mean scores of the expectancy ratings indicate that the respondents strongly associate new technology, environmental soundness, and new fuel types with more fuel economical vehicles. Again, the ratings on new technology and environmental soundness show only low variance in contrast to the other items where the respondents differ more in their appraisal. Also less power, slower acceleration, and smaller size seem to be characteristics commonly associated with such vehicles with mean scores above or slightly above the scale mean of 3. A pioneer image is also perceived by the respondents, whereas decreased safety, less comfort and a boring image are least connected to more fuel economical vehicles.

An exploratory factor analysis using the products of multiplying expectancy and valence (cf. Section 3.4) reveals four factors underlying these rat-

ings (see Table 3.3) which can be described as expectation and valence of 1) environmental protection by technological progress, 2) less power and smaller size, 3) decreased safety and comfort, and 4) attractiveness and pioneer image. These factors are also found by factor analyses which are conducted separately on the expectancy and on the valence ratings.

Table 3.3. Dimensions and factor loadings resulting from an exploratory PCA on the expectancy and valence measures concerning conceivable characteristics of more fuel economical vehicles (N ≥ 298)

Conceivable characteristics of more fuel economical vehicles	Factor 1 (ProgEnv)	Factor 2 (PowSize)	Factor 3 (SafeComf)	Factor 4 (AttrImage)
cars which save fuel through new technology	.829			
cars which use a new fueltype	.680			
cars which are environmentally sound	.678			
cars with a boring image	-.467			
cars with a less powerful engine		.879		
smaller cars		.831		
cars which accelerate less than other cars		.654		
cars which provide less safety than other cars			.857	
cars which are less comfortable			.833	
cars which have a pioneer image				.774
cars which are more expensive than other cars				.736
attractive cars				.618
Explained variance of factors	17.20	17.14	13.93	13.90

Note. The PCA used the products of multiplying the respective expectancy and valence ratings. The numbers represent the loadings above .4 after factor rotation according to the Varimax criterion and selection of four factors considering the Kaiser-Guttman criterion, Scree plot, and theoretical reasonability.
ProgEnv= expectation and valence of environmental protection by technological progress, PowSize = expectation and valence of less power and smaller size, SafeComf = expectation and valence of decreased safety and comfort, AttrImage = expectation and valence of attractiveness and pioneer image.

In literature, it has been discussed how such expectancy and valence measures should be combined, mainly based on statistical argumentation (cf. Gagné & Godin, 2000). However, a generally accepted procedure is yet to be found. Because of scaling problems when multiplying two variables which are not measured on a ratio scale (Gagné & Godin, 2000), using only the valence ratings may be a reasonable solution. For the case of salient associations, differences in the respondents' evaluation should be predictive for the purchase of less CO_2 emitting vehicles. As we did not ask the respondents

for their salient beliefs beforehand but instead let them rate what characteristics they associate mainly with more fuel economical vehicles, we will focus on the associations which seem to be more important in the respondents' mind.

As salient associations we regard the items underlying the first two factors as these items get average expectancy ratings in the upper range of the scale. However, the items of the first factor concerning environmental protection by technological progress show little variation between the respondents with regard to their evaluation; hence, we concentrate on the evaluations of the items loading on the second factor. Thus, as indicators for the latent attitude variable in the SEM analyses, the valence ratings of these three items (cars with a less powerful engine, cars which accelerate less than other cars, and smaller cars) were included into the measurement model.

CO_2 emissions of recently bought new vehicles. After correcting CO_2 emissions of the vehicles according to their respective purchase year such that they are comparable for market conditions of 2006 (cf. Section 3.2), the average CO_2 emissions of the respondents' vehicles have a mean of 185.77 g per km (min. = 104.00, max. = 345.85, *S.D.* = 41.29). A t-test with regard to deviations from the average of new car registrations in Switzerland in 2006 (187 g CO_2/km, cf. Section 3.2) reveals no significant differences.

4.2 Test of the measurement models

The confirmatory factor analysis which was conducted to test the measurement models of the predictor variables confirmed the seven factor structure after the following modifications. The following 3 items had to be removed because of cross loadings: (1) Social norm item 3 (cross-loading on PBC, personal norm and on social norm); (2) response efficacy item 6 (cross-loading on social norm and response efficacy); (3) symbolic motives item 2 (cross-loading on valence of less power and size and symbolic motives). The two items response efficacy 1 and 2 were deleted because they exhibit high residual covariances. Only 2 of 5 items to assess PBC possess factor loadings above .4 which was considered as satisfying. Thus, the PBC items 1, 2 and 4 were removed. Finally, the symbolic motives item 4 was removed because its error correlates with the symbolic motives item 6. The measurement models of the constructs personal norm, problem awareness and valence of less power and size could be confirmed without modification.

Table 3.4. Measurement models for the seven latent model variables (λ = standardized factor-loadings)

Latent variable and associated indicators	*λ*
Social norm	
Most people who are important for me expect me to drive a car with the least possible fuel consumption (or no car at all).	.74
Most people who are important for me drive more fuel economical cars or would drive such cars.	.70
Perceived behavioral control (PBC)	
I know where to get the information which are necessary to choose a more fuel economical car.	.41
Currently, there is no car which is more fuel economical appropriate for me. (recoded)	.52
Personal norm	
No matter, what other people do, I think it is the right thing to choose a car with a fuel consumption as low as possible.	.82
The purchase of a vehicle with a rather high fuel consumption does not gnaw at my conscience. (recoded)	.52
When making a trip by car, it should burden climate and oil reserves as little as possible.	.66
Response efficacy	
Buying a more fuel economical vehicle, I can effectively contribute to the protection of the climate.	.88
Buying a more fuel economical vehicle, I can effectively contribute to save oil.	.58
It doesn't matter what car I buy as it makes no difference regarding protecting our climate. (recoded)	.73
Problem awareness	
People exaggerate the role of car traffic as the cause for climate change. (recoded)	.81
The change of the climate should not be dramatized. (recoded)	.76
People exaggerate the role of car traffic for oil consumption. (recoded)	.71
When thinking of the consequences of traffic on the climate, I am very worried.	.57
When thinking of how we deal with our oil supplies, I am very worried.	.52
I don't believe that oil depletion is as bad as often claimed. (recoded)	.50
Symbolic motives	
It is important to me to drive a car which appeals to me.	.56
For me, the car has instrumental functions only. (recoded)	.71
To me, cars are very important.	.48
It does not matter to me which type of car I drive. (recoded)	.65
Valence of specific consequences (attitudinal aspect)	
Within car purchase, how do you evaluate a smaller car?	.53
Within car purchase, how do you evaluate a car with a less powerful engine?	.96
Within car purchase, how do you evaluate a car which accelerates less?	.50

The statistical fit of the revised measurement models presented in Table 3.4 is acceptable (χ^2 = 242.99, df = 217, p = .11; *GFI* = .93, *AGFI* = .91, *CFI* = .93, *RMSEA* = .02). The significant correlations between the latent factors of the measurement models are presented in Table 3.5. Overall, the correla-

tions between personal norm and the other model variables are the highest. Social norm and PBC, in contrast, show the fewest significant correlations.

Table 3.5. Significant estimated correlations between the latent model variables

Variables	1	2	3	4	5	6
1. Personal norm	-					
2. PBC	.30**	-				
3. Social norm	.20**		-			
4. Problem awareness	.52***		.18*	-		
5. Response efficacy	.47***	.31*		.36***	-	
6. Symbolic motives	-.42***			-.44***		-
7. Valence of less power and size (attitudinal aspect)	.42***			.33***	.25**	-.41***

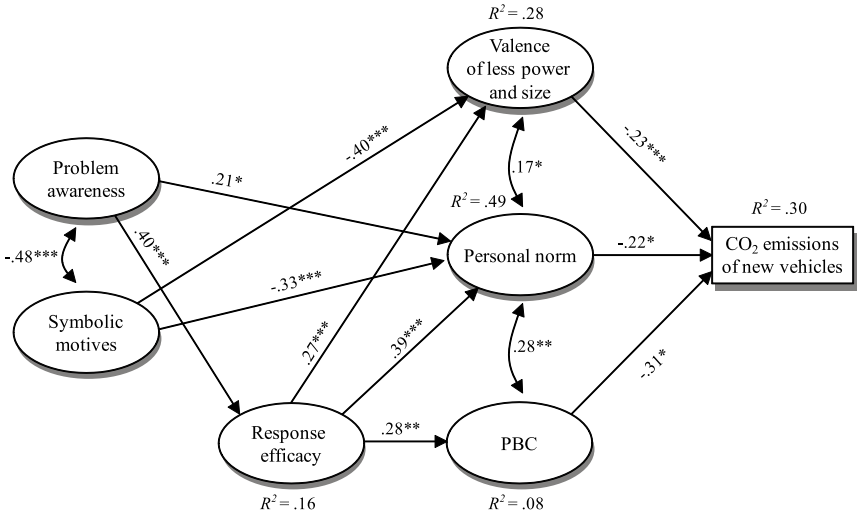
.*$p \leq .05$; **$p \leq .01$; ***$p \leq .001$.

4.3 Structural equation modeling analyses

The assessment of the theoretical model (cf. Figure 3.3) by means of the structural equation approach yielded the following goodness-of-fit statistics: $\chi^2 = 255.04$, df = 213, $p = .03$; *GFI* = .93, *AGFI* = .91, *CFI* = .89, *RMSEA* = .03. These overall results as well as a closer look into the estimated coefficients and the modification indices reveal some evidence for a limited fit of the model.

Personal norm, valence of less power and size (attitudinal aspect), and PBC could be confirmed as significant direct predictors of the dependent variable CO_2 emissions of new vehicles. As factors directly influencing the predictors personal norm, valence of less power and size, and PBC the variables problem awareness, response efficacy, and symbolic motives could be empirically supported. However, social norm did not prove to influence the direct predictors.

With regard to a better fit of the model, the modification indices suggested a negative correlation of problem awareness and symbolic motives which was not specified in the original model. Theoretically, it seems reasonable that people with strong symbolic motives attached to vehicles are rather less interested in or try to avoid information on environmental problems associated with car use. Vice versa, people who are aware of these problems might perceive vehicles more pragmatically, i.e., for them symbolic motives might be less important.



$\chi^2 = 219.07$, df = 197, $p = .13$; *GFI* = .93, *AGFI* = .92, *CFI* = .94 , *RMSEA* = .02

*Figure 3.4. Significant results of the estimated SEM: significant standardized structural coefficients (*p ≤ .05; **p ≤ .01; ***p ≤ .001), explained variances, and model fit indices.*

Hence, based on these cues and theoretical assumptions, we suggest an adapted model (see Figure 3.4) resulting from few modifications to the original model: deletion of the non-significant indirect predictor social norm; deletion of the non-significant correlation between PBC and valence of less power and size; specifying a correlation between problem awareness and symbolic motives.

According to the model fit indices depicted in Figure 3.4, the suggested structural model produced an acceptable fit to the data. Together, the three direct predictors valence of less power and size, personal norm, and PBC explain 30% variance of the CO_2 emissions of the vehicles in question.

5 Discussion and conclusion

The aim of this paper was to test an integrated model of psychological determinants influencing CO_2 emissions of new vehicles together with the associated hypotheses. Based on a meta-analytic SEM of psychological

determinants of environmental behaviors by Bamberg and Möser (2007), this model integrates the TPB and the NAM variables as determining CO_2 emissions of new vehicles. Specifically for car purchase, symbolic motives were hypothesized as additional indirect predictor. Finally, we wanted to analyze the image people associate with (more) fuel economical vehicles.

The results of the SEM analyses did not fully support the original postulated model. Based on a few modifications indicated by estimation results and theoretical assumptions, an adapted model could be suggested which reached an acceptable model fit. The attitudinal aspect valence of less power and smaller size, personal norm, and PBC could be proven as direct predictors of the CO_2 emissions of recently bought new vehicles. Together, they can explain 30% variance of the dependent variable CO_2 emissions of new vehicles. In Bamberg and Möser's (2007) meta-analysis of 46 studies applying the TPB, NAM or similar models to different environmental behaviors, on average 27% variance of self-reported environmental behavior was explained. Thus, the result of our model seems to be in an acceptable range. Please note that our study uses a dependent variable which measures actual instead of self-reported behavior.

As hypothesized, the construct of symbolic motives has significant negative influence on two of the direct predictors – personal norm and valence of less power and size – and thus, favors indirectly the ownership of a vehicle with higher CO_2 emissions. Besides this negative impact of symbolic motives, the three direct predictors valence of less power and size, personal norm, and PBC are positively influenced by problem awareness and response efficacy. However, an influence of social norm could not be proven. We could imagine that the phrase of the first item assessing social norm, "… expect me to drive a car with the least possible fuel consumption", was too strict and should better be replaced by, e.g., "…expect me to drive a rather fuel economical car".

Our results concerning the characteristics associated with more fuel economical vehicles reflect the salience of the positively valued features of new technology and alternative fuels. As well, smaller size and less power are common associations; however, the respondents differ in their attitude towards these characteristics.

According to the need stated at the beginning (cf. Bamberg et al., 2007), our study constitutes a contribution to the development and testing of theoretical frameworks for people's environmental decisions which integrate different motives and specify their interaction and relative importance, applied

here to the specific topic of car choice behavior. It indicates which psychological determinants could enrich models to explain and forecast car choice behavior with the aim of developing effective measures to change behavior.

However, for the interpretation of these results, it is important to keep in mind the time context of the survey. It may be allowed to speak of an early stage of public attention towards topics related to the fuel consumption of vehicles. The two survey waves were conducted in summer of 2005 and 2006 when the oil price was still below 70 US-$/barrel (2005) and 80 US-$/barrel (2006), whereas in 2007, it has dramatically been rising to almost 100 US-$/barrel. As well, public's attention to and media presence of climate change have increased considerably since the release of part one of a series of reports of the IPCC's fourth assessment (IPCC, 2007b). Thus, the variables in the focus of this study as well as their associations may be changing. For instance, consumers' associations with more fuel economical vehicles and their evaluation might be changing; fuel economy and efficiency, respectively, might gain more symbolic value, and hence, symbolic motives might begin to add positive influence on the purchase of less CO_2 emitting vehicles; social norms which support pro-environmental vehicle purchase more strongly might develop.

In the context of the theoretical implications, we also need to discuss the critical aspects of our study. First, one has to keep in mind that for testing our hypotheses we used cross-sectional correlational data which do not reflect causality. Hence, our interpretations are based on theoretical assumptions.

Furthermore, the vehicles in question have been bought up to three years before the psychological constructs were assessed. Thus, it is possible that the psychological factors have changed since the purchase of the vehicle and that the associations would be higher if the predictors would have been measured at the time of the purchase.

Another issue concerns the replacement of the term efficient through "more fuel economical" in the questionnaire based on the following reasons: The term "efficient" may not be understood by everybody in the same way. An explanation in the questionnaire, however, could draw the respondents' attention on the abovementioned differences within the same car size class of which they may not be aware by themselves. By avoiding such an explanation and speaking of more fuel economical vehicles, it should be possible to reveal which options consumers may think of with regard to a reduction of fuel consumption within car purchase. However, these associations with the term "more fuel economical" influence the responses to other items using

this term. One resulting problem, e.g., might be a reduction of variance of the PBC items concerning the evaluation of more fuel economical vehicles. Thus, the prevailing associations assessed by the expectancy measures should be kept in mind when interpreting the data.

Last, but not least, we want to emphasize the practical implications of this study: Our results indicate that information and prompts, such as fuel efficiency labels, to help consumers to better identify fuel-efficient vehicles could be effective. The results on the characteristics associated with more fuel economical vehicles suggest to better inform people that such vehicles do not necessarily need to be smaller or accelerate less in most everyday situations. In general, fuel efficiency should be promoted as a popular feature. The public sector could take a leading role and make fuel efficiency a prominent selection criterion for its car fleets. As well, financial incentives could emphasize the social desirability of a change of purchase behavior. Personal norm should be enhanced by emphasizing the effect of individual behavior. In general, various measures starting at different relevant factors and supporting each other should be combined.

Chapter IV

Psychological factors influencing fuel consumption and CO_2 emissions within intended and actual car purchase

Abstract

Consumers' adoption of fuel-efficient vehicles is crucial with regard to reducing fuel consumption of road transport. Investigating reasons for the gap between intention and revealed behavior can contribute to a more effective promotion of efficient vehicles. We compare psychological determinants of stated importance of fuel consumption vs. actual behavior. For behavior, four proxies are applied accounting differently for resources and needs indicated by household type and socio-economic status. Survey data from Switzerland is used for (1) potential new car buyers and (2) owners of recently purchased new vehicles. The results indicate that stated importance of fuel consumption is mainly expressed according to an inner feeling of obligation and inhibited by symbolic motives (motives to express one's self and one's social position through one's car). When it comes to car purchase, the evaluation of less vehicle power and smaller size and perceived behavioral control add considerable explanatory power. These results, however, vary considerably by different behavioral proxies which should therefore be chosen carefully. A proxy adjusted for household type considering other vehicles in the household seems to meet better differences in environmental behavior due to consumers' living situation. Policy measures to promote fuel-efficient vehicles which account for the relevant psychological factors are outlined.

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1 Introduction

Improving fuel efficiency of new vehicles is one of the most important paths to mitigate greenhouse gas emissions and dependence on fossil energy (IEA, 2006; IPCC, 2007a). In the last 10 years, average CO_2 emissions of European new car registrations decreased by approximately 1% per year. The decrease would have been greater if consumers had not purchased bigger and faster cars (Zachariadis, 2006). Hence consumer adoption of fuel-efficient vehicles plays a crucial role (cf. DeCicco, 2006).

Thus, actual car purchase behavior did not reveal the importance that consumers generally attribute to fuel consumption in surveys (e.g., Boardman et al., 2000). To promote fuel-efficient vehicles more effectively, understanding the barriers for action is crucial. These might be identified by comparing determinants which explain the stated importance of fuel consumption with those that explain actual purchase behavior.

Research to identify factors affecting car choice has mainly focused on sociodemographic characteristics of consumers (Choo & Mokhtarian, 2004).

Stern (2000) points out that *sociodemographic* factors like income or education may be important if the behavior in question depends on particular capabilities or resources such as money or knowledge. In addition, we argue that factors such as household type and socio-economic status can also be indicators of certain needs which influence a particular behavior. For instance, the size of one's household indicates a need for more transport capacity and thus makes the choice of a small vehicle less likely (cf. Choo & Mokhtarian, 2004).

However, despite certain constraints indicated by sociodemographic variables, there is scope to act pro-environmentally. Large differences in CO_2 emissions still exist between different versions of almost any given vehicle model (de Haan et al., 2009). For example, the Volkswagen Golf, the most sold passenger car in Europe, was available in 2008 with engine configurations ranging from 119 to 257 g CO_2/km.

Within this range we assume that *psychological* factors, such as attitudes towards more fuel economical vehicles or awareness of problems related to fuel consumption, explain, to a large extent, the energy relevant purchase decision of consumers. Various findings on close domains like mobility (Hunecke et al., 2007) or environmental purchase behavior (Dietz et al., 1998; Straughan & Roberts, 1999; Tanner & Wölfing Kast, 2003) support our as-

sumption that psychological variables have significant influence besides sociodemographic variables.

It might seem straightforward to solely judge environmental behavior *absolutely*, i.e. with regard to its environmental impact. If, however, the chosen car size is largely influenced by consumers' living situation, then, consequently, there is not a unique yardstick directly applicable to everyone in order to assess whether the environmental impact of their cars is below, above, or on average. Alternatively, environmental impact could be compared *relative* to a reference group defined by a similar living situation. Such a relative approach might, e.g., reveal better whether measures lead to behavioral changes among groups which differ considerably in relevant aspects of their living situation.

The present article uses the concepts and main findings of Peters, Scholz, and Gutscher (2008), who studied psychological factors influencing CO_2 emissions within actual car purchase. We analyze the role of psychological factors in two settings. With regard to *intended* purchase behavior (Analysis 1), we focus on the stated importance of fuel consumption within the next car purchase as proxy for the intention to buy a fuel-efficient vehicle. With regard to *actual* purchase behavior (Analysis 2), we focus on absolute CO_2 emissions of recently purchased new cars and three additional behavioral proxies.

2 Factors influencing intention and actual car purchase

2.1 Psychological variables

Our set of psychological factors to explain CO_2 emissions of chosen vehicles is based on Bamberg and Möser (2007). Their model results from a meta-analysis of studies on environmental behavior and integrates the psychological theories most applied to environmental behavior: The theory of planned behavior (TPB; Ajzen, 1991) and the norm-activation model (NAM; Schwartz, 1977).

The TPB assumes that behavior is directly influenced by a person's intention to perform it. Intention, in turn, is determined by (1) a person's attitude towards the behavior, defined as an overall evaluation of the behavioral consequences with regard to their subjective expectancy and evaluation, (2) subjective norms, referring to the perceived expectations of other important

persons (we will speak of social norms in the following), and (3) the perceived behavioral control (PBC), defined as a person's perceived power to perform the behavior. Besides PBC's indirect influence on behavior via intention, a direct one is assumed to the extent that the person perceives her objective power to perform the behavior accurately.

Studies using the NAM explain environmental behavior as being influenced by (1) a personal ecological norm, defined as a strong intrinsic feeling of obligation to engage in the specific behavior. Important preconditions for the development and activation of this personal norm are (2) the awareness of an environmental problem as well as (3) the awareness of environmental consequences of one's own behavior, denoting the perception of own behavioral options that have an effect on the problem. This construct has appeared in literature under different labels; we use the term response efficacy (cf. Lam & Chen, 2006).

Peters, Scholz, and Gutscher (2008) applied this framework to analyze CO_2 emissions of recently purchased new cars. They also regarded symbolic motives (i.e., motives to express one's self and one's social position through the car owned; cf. Steg, 2005). The present paper, aiming at the comparison of determinants of intended vs. actual car purchase, adopts their final model which is depicted in Figure 4.1.

Accordingly, CO_2 emissions of the respondents' vehicles depend directly (1) on the evaluation of less power and smaller size which the respondents commonly associated with more fuel economical vehicles, (2) on their personal norm to buy a more fuel economical vehicle, and (3) on their respective PBC. Together, these variables explain 30% variance of the dependent variable. These predictors, in turn, are based on (1) the awareness of problems such as climate change or dependence on fossil fuels, (2) perceived response efficacy of one's own behavior to do something about these problems, and (3) symbolic motives. The hypothesized indirect influence of social norm on CO_2 emissions via the direct predictors was not observed.

Symbolic motives which positively influence CO_2 emissions in this model are not necessarily linked to characteristics that lead to an increase of CO_2 emissions of a chosen vehicle. However, at the time of our survey (see next section), traditional symbolic vehicle characteristics such as vehicle size and performance are assumed to be still of considerable symbolic value in contrast to fuel economy and low CO_2 emissions, although this may be changing.

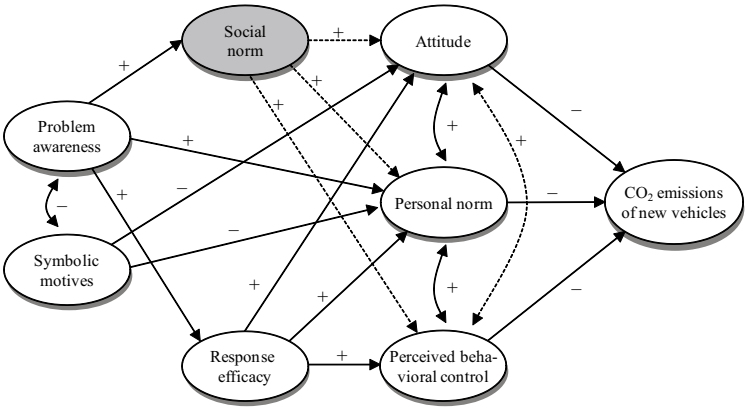


Figure 4.1. Model to explain CO_2 emissions of new vehicles suggested by Peters, Scholz, and Gutscher (2008). The grey ellipse and the dotted arrows indicate the psychological variable and the hypothesized relations, respectively, which were deleted as they did not significantly contribute to the explanation of the dependent variable. "+" indicates positive influence, i.e. an increase in the influencing variable leads to an increase in the variable which is influenced, "-" indicates negative influence, i.e., an increase in the influencing variable decreases the variable which is influenced.

2.2 Sociodemographic variables

Though models in literature which explain vehicle-type choice distinguish vehicle types by make and model at best, which still allows large differences in energy demand existing within vehicle models (cf. de Haan et al., 2009), their empirical findings provide clues to which sociodemographic characteristics play a role for CO_2 emissions of a chosen vehicle. In their review, Choo and Mokhtarian (2004) identified income, household size, education, age, and gender as affecting vehicle-type choice. With respect to CO_2 emissions, we discuss these variables in the following.

Findings of Black et al. (1985) suggest that differences in *income* might be more important in high-cost activities (like owning a car) than in low-cost activities. There are three routes to cars with lower CO_2 emissions (de Haan et al., 2009): Less powerful (i.e. smaller) engines, smaller cars, and new technology (such as hybrids). With the first two routes, the costs of car purchases decline. New technology is the only route with higher costs. Lower income thus favors the purchase of a vehicle which is smaller or has a small-

er engine and, thus, emits less CO_2 (Choo & Mokhtarian, 2004). It might inhibit the purchase of new technology, such as hybrid vehicles (de Haan et al., 2006). Despite the fact that under European fuel taxes, lifetime costs of hybrids are comparable to non-hybrid cars, higher investment costs can become a barrier as households hardly perform a full lifetime cost calculation (cf. Turrentine & Kurani, 2007).

With regard to *household size*, larger households, especially those with children have a greater instrumental need for larger cars (cf. Choo & Mokhtarian, 2004). As option to reduce CO_2 emissions of a vehicle, a smaller engine seems more realistic for them than a smaller car or a car with new technology (as such households more often have financial restrictions).

Education and knowledge about environmental issues are, in general, - moderately - correlated (Fransson & Gärling, 1999). Higher education might favor understanding the climate mitigation potential of individual car purchases. However, as higher education correlates positively with income, consumers with higher education tend to drive more expensive vehicles (Choo & Mokhtarian, 2004) with usually higher CO_2 emissions.

As well, the empirical positive influence of *age* on size and price of purchased vehicles (Choo & Mokhtarian, 2004) may be partly explained by effects of confounded variables such as income and household type.

Concerning *gender*, engine power, acceleration and status seem to be less important to women than to men (Mienert, 2002); hence, women might drive vehicles which emit relatively less CO_2. However, studies show that men are generally more interested in technology (e.g., Klocke, 2002a) which favors an early adoption of vehicles with new and efficient technology. Thus, the influence of gender might be expected in the other direction as well.

Based on this overview on sociodemographic variables, we expect that mainly household type (i.e., household size and composition) as well as socio-economic status influence choice towards vehicles emitting more CO_2. Socio-economic status is classically determined by income but as well by other variables such as education and occupational level (cf. Tanner & Wölfing Kast, 2003).

2.3 Intention-behavior gap

TPB attributes intention a key role in the explanation of behavior. A gap between intention and behavior, i.e., differences in the explained variance of intention vs. behavior, is a common finding in TPB studies. In meta-analyses

of TPB applications pertaining to different behavioral domains (Armitage & Conner, 2001) as well as specifically to environmental behavior (Bamberg & Möser, 2007), on average 27% of behavior is explained, whereas intention is usually explained to a considerably higher degree (between 32% and 52% in the referenced meta-analyses). However, when behavior measures are objective, less variance of behavior is explained than when it is self-reported (R^2 = .21 vs. R^2 = .31; Armitage & Conner, 2001). This intention-behavior-gap is also indicated by the observed intention-behavior-correlations: r = .47 are reported by Armitage and Conner (2001), r = .52 by Bamberg and Möser (2007).

According to Webb and Sheeran (2006), three classes of variables may moderate the intention-behavior relation: (1) Theoretically specified factors, such as PBC, which may influence the translation of intentions into behavior, (2) measurement factors, such as the type of behavior measure (cf. above) and the time interval between the measure of intention and behavior, and (3) publication bias (studies with low and insignificant intention-behavior correlations might have less chance of publication).

Results of Klocke (2002b) also indicate differences between the prediction of intention and of actual behavior. A significant contribution of intention to the explanation of fuel economy of an owned vehicle was not observed; but a direct influence of the attitude towards the purchase of a less environmentally harmful vehicle was found. Intention was mostly influenced by other variables than those influencing the behavior itself. Klocke (2002b), however, regards only one vehicle purchase and does not analyze differences with respect to household type or socio-economic status.

2.4 Research objective

The goal of this study is to compare psychological factors which explain *intended* vs. *actual* car purchase with regard to fuel consumption and CO_2 emissions. First (Analysis 1), we investigate the role of psychological variables when influencing stated importance of fuel consumption within the next vehicle purchase (as drawn in Figure 4.2). Next (Analysis 2), we broaden the analysis of actual behavior by studying the role of the same psychological variables for four behavioral proxies which differ according to if and how they take resources and needs indicated by household type and socio-economic status into account.

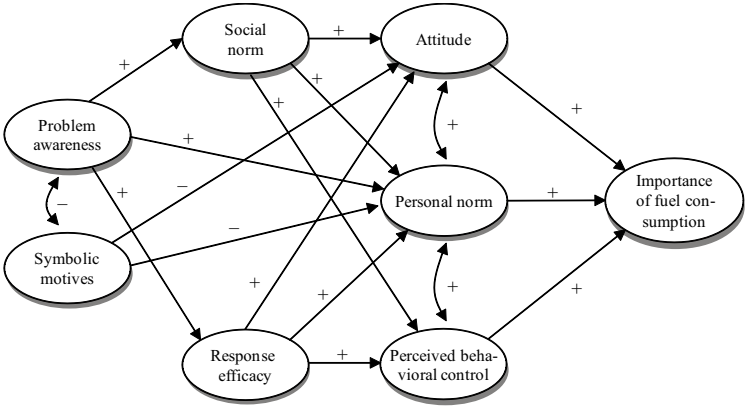


Figure 4.2. Theoretical model to explain importance of fuel consumption in car purchase, adapted from Peters, Scholz, and Gutscher (2009). "+" indicates positive influence, i.e., an increase in the influencing variable leads to an increase in the variable which is influenced, "-" indicates negative influence, i.e., an increase in the influencing variable decreases the variable which is influenced.

In Analysis 1, as proxy for *intention*, the dependent variable importance of fuel consumption concerns *future purchasing behavior*. In contrast, the dependent variables of Analysis 2 focus *actual behavior* via *past vehicle purchases*. Though the vehicle data needed to provide CO_2 emissions of the vehicle is self-reported by the respondents, we regard the behavioral proxies based on this data as objective measures as it might be hardly influenced by the well-known biases when people report their own behavior in questionnaires (Krosnick, 1999). We will compare the results of the two analyses and discuss three aspects: (1) theoretical insights into the nature of the psychological constructs, (2) consequences of possible behavioral proxies and hints for possible designs of such proxies, and (3) recommendations for promoting fuel-efficient vehicles.

3 Method

3.1 Survey

Our data results from a two-wave survey. In Wave 1, two different questionnaires were sent out in June 2005 to 5890 households, randomly chosen

from the phone book, in the German- and French-speaking parts of Switzerland. Only the first questionnaire, which was sent out to two thirds of the households, contained the module with the dependent variable of Analysis 1, i.e. the importance of fuel consumption. Items on sociodemographic variables and the modules relevant to Analysis 2, studying actual car purchase behavior, were included in both questionnaires. In both questionnaires, we asked that person to answer (1) who was likely to buy the next car, or (2) who had bought the last car (or was significantly involved in the decision process), or (3) who used to drive the most.

From overall 2333 respondents (response rate = 39.61%), 1545 (66.22%) were both willing to participate again in Wave 2 and still reachable at their address. Of these, 1150 (response rate = 74.43%) returned the questionnaire of Wave 2 which was sent out one year later in June 2006. Data sets were excluded if the two survey waves were not filled out by the same household member or if more than 50% of the items measuring our predictor variables are missing. Otherwise, missing data on the psychological variables was imputed by regression.

Importance of fuel consumption. In the first questionnaire of Wave 1, the respondents were asked to put a set of 12 attributes in order (safety, design, engine size, purchase price, car size, gear type, brand, fuel consumption, fuel type, four-wheel drive, exhaust fumes, acceleration). The response scale consisted of four categories from "at first I decide…" to "at the end I decide…", where respondents did not tick any box if they felt that they did not consciously decide about a given attribute at all. We assume such a chronological ordering of vehicle attributes to reflect their importance as well and to be easier for respondents and less susceptible to effects of social desirability than the rating of importance of vehicle attributes separately. After post-processing, we used the rank of the attribute fuel consumption (ranging from 13 [decided at first] to 1 [assigned to non-ticked attributes]) as an indicator for its importance. In order to reduce socially desirable responses, this item and the psychological predictors were purposely measured in two different survey waves.

Vehicles in possession. In Wave 1, the respondents were asked to give detailed data on all cars currently owned by their household such as brand, model, fuel type, engine capacity, gear type, year of purchase, and vintage. This data allows for an identification in the type registration database, yielding further vehicle characteristics (size, weight, fuel consumption, CO_2

emissions). In Wave 2, the respondents were asked for any changes in the vehicle stock of the household.

Psychological variables. For each of the psychological variables (social norm, PBC, personal norm, response efficacy, problem awareness, symbolic motives, and attitude), several items were included in Wave 2. Unless otherwise stated, respondents rated their agreement on a 5-point scale (from 1 = not at all the case to 5 = very much the case). Negatively formulated items were reversed in coding. Table 4.2 lists the items selected to compute the psychological variables. Two different approaches were used for the attitude measure: First, subjects were asked to rate their general attitude towards more fuel economical vehicles. In addition, to measure underlying beliefs about the expectancy and evaluation of particular outcomes, respondents first assessed a set of conceivable associations on how much they correspond to their image of more fuel economical cars. Subsequently, they were asked to assess how negative vs. positive they would rate these criteria within car purchase. In order to enter a multi-item variable representing attitude, we used only three of the evaluation items (cf. Peters, Scholz, & Gutscher 2008).

3.2 Proxies for actual car purchase

We use type-approval CO_2 emissions as an indicator of vehicle energy demand as we do not regard behavioral options that reduce CO_2 but do not reduce energy demand (alternative fuels like bio-fuels, hydrogen, compressed natural gas). In order to compare CO_2 emissions of vehicles bought in different years, we normalize CO_2 emissions relative to the market average of 2006, using average CO_2 of new registrations per fuel type and year. In the following, this normalized CO_2 data is always applied so that all vehicles are comparable for the market conditions of 2006.

The following four behavioral proxies are applied.

(1) Proxy ABS: *Absolute* CO_2 emissions of the most recently purchased vehicle, which does not consider respondent's life circumstances or other vehicles in the household.

(2) Proxy SES: CO_2 emissions of the most recently purchased vehicle *adjusted for socio-economic status*. As socio-economic status is assumed to influence car size, we relate CO_2 emissions to the shadow of a vehicle.

(3) Proxy HHT: CO_2 emissions of the most recently purchased vehicle *adjusted for household type* (household size and composition) by applying the *OECD-modified equivalence scale* (OECD, n.d.). This scale assigns a

weighting of 1 to the household head, 0.5 to each additional adult, and 0.3 to each child.

(4) Proxy CUM: *cumulated CO_2 of all vehicles in the household bought and built since 2000, adjusted for household type* (cf. proxy HHT).

3.3 Samples

Sample 1 for Analysis 1 consists of those respondents who could imagine buying a *new* vehicle within the next 10 years ($N_1 = 265$). For Analysis 2, we use the sample underlying the study of Peters, Scholz, and Gutscher (2008) which consists of those 302 respondents whose households have bought a new vehicle since 2002 (*Sample 2*). Table 4.1 presents the characteristics of each sample.

Table 4.1: Sociodemographic characteristics of Sample 1 and Sample 2

Characteristics	Sample 1	Sample 2
N	265	302
Gender: % male	72.2	79.0
Age		
mean (*S.D.*) in 2005	50.87 (14.21)	50.04 (13.85)
min.	19	18
max.	85	82
Median monthly household income (EURO[a])	5'351-6'650	5'351-6'650
Household size and structure		
average no. of all persons (*S.D.*)	2.50 (1.21)	2.65 (1.18)
average no. of adults (*S.D.*)	1.99 (0.75)	2.06 (0.68)
households with children (%)	30.47	33.79
for subsample with children: average no. of children	1.77	1.79
No. of vehicles		
% households with 0 vehicle	4.91	/
% households with 1 vehicle	55.47	47.67
% households with 2 vehicles	33.58	45
% households with 3 or more vehicles	6.03	7.33

[a]applied CHF/EUR exchange rate = 1.5

The two samples are partly overlapping, with 131 respondents included in both samples. Analyses of the non-overlapping subsamples show that no relevant differences exist between these complements with regard to age, edu-

cational level, household income, number of adults and number of children living in the household.

3.4 Analyses

Principal component analyses (PCAs) and reliability analyses (Cronbach's alpha) were carried out with the item sets used by Peters, Scholz, and Gutscher (2008). These analyses were conducted for each subsample as well as for the combined sample. The final variables were constructed by computing the individual average scores across the associated items. Subsequently, the correlations between all psychological and all dependent variables were analyzed to get an impression of the bivariate relationships underlying the following analyses.

To test the theoretical structural equation model (SEM) for the dependent variable stated importance of fuel consumption (cf. Figure 4.2), we conducted SEM analyses with Amos 6.0 (Arbuckle, 2005). Within these analyses, generalized least squares estimation was applied because the assumptions of normal distribution for most of the model variables and of interval scale quality for the dependent variable were not completely fulfilled. Although the dependent variable is of ordinal quality, its skewness (g_1 = -0.993) and kurtosis (g_2 = -0.195) are still in a range which legitimates the application of structural equation modeling (Schumacker & Lomax, 2004).

Considering the sample size for Analysis 1 (N_1 = 265), our theoretical SEM model contains a relatively large number of constructs and associated items. As recommended in such cases by Baumgartner and Homburg (1996), the variable scores calculated across the indicator items were entered as observed variables to estimate the latent variables (except for the single-item variable importance of fuel consumption). Measure unreliability was taken into account by fixing the error variance of the indicator to (*1 - reliability) times the variance of the indicator*. As measure of reliability Cronbach's alpha was used, although this coefficient usually exaggerates unreliability of measurement as it represents, in general, a rather low bound on reliability (Baumgartner & Homburg, 1996). The final model which we suggest was achieved after some modifications to the theoretical model based on modification indices and theoretical assumptions. These modifications will be described in the results section. Moreover, non-significant paths which did not prove to have any significant direct or indirect influence on the main dependent variable were deleted.

In order to explore possible proxies of a person's car purchase behavior with regard to CO_2 emissions, we analyzed the correlations (Spearman's rho) of the proxies with importance of fuel consumption (within the overlapping subsample of the two samples of analyses) and conducted separate linear regression analyses of the psychological variables on each behavioral proxy.

For reasons of better comparison, a linear regression analysis on importance of fuel consumption was conducted as well, which is more simplified than the SEM method and does not consider interactions of the predictors. We also regard the linear regression as a "test of robustness" on the SEM results. In a nutshell, comparing the results of methods which are related but differ in their complexity and assumptions can indicate if results depend on a specific method and its assumption or if they are robust. As, again, the scale quality of the ordinal dependent variable of Analysis 1 does not fulfill the assumption of linear regression, the results of this regression analysis should be interpreted carefully. During the analyses, estimation errors by multi-collinearity were controlled: Variance inflation factors of all variables were $\leq$ 1.57 which indicates that multi-collinearity was not a problem.

4 Results

4.1 Descriptive results

Psychological variables. The results of the PCAs confirmed the factor solution of Peters, Scholz, and Gutscher (2008) which consists of seven unidimensional scales for social norm, PBC, personal norm, response efficacy, problem awareness, symbolic motives, and evaluation of less vehicle power and smaller size. However, as we entered variable scores calculated across the indicator items and specified their measurement error by means of their Cronbach's alpha (cf. Section 3.4), the Cronbach's alpha of PBC leads to a rather high measurement error for this scale. Thus, to reduce its measurement error, we added one additional item ("In my current life situation, I cannot consider a lower fuel consumption."). The psychological variables and their associated items are displayed in Table 4.2, along with reliability, explained variance and factor loadings calculated within each subsample and for the overall sample.

Table 4.2. Psychological model variables and associated indicators, based on PCAs for each variable which confirmed one-factor solutions for each scale

Latent variable and associated indicators		**Loadings for sample (*N*)**		
		1 (265)	**2 (302)**	**overall (435)**
Social norm	Explained variance	76.94	76.02	75.41
	Cronbach's alpha	$r = .54$	$r = .52$	$r = .51$
Most people who are important for me expect me to drive a car with the least possible fuel consumption (or no car at all).		.88	.87	.87
Most people who are important for me drive more fuel economical cars or would drive such cars.		.88	.87	.87
Perceived behavioral control (PBC)	Explained variance	49.19	49.22	48.03
	Cronbach's alpha	.47	.47	.45
I know where to get the information which are necessary to choose a more fuel economical car.		.64	.65	.61
Currently, there is no car which is more fuel economical appropriate for me. (recoded)		.75	.71	.72
In my current life situation, I cannot consider a lower fuel consumption. (recoded)		.72	.75	.74
Personal norm	Explained variance	64.34	63.65	64.30
	Cronbach's alpha	.71	.69	.70
No matter, what other people do, I think it is the right thing to choose a car with a fuel consumption as low as possible.		.86	.85	.85
The purchase of a vehicle with a rather high fuel consumption does not gnaw at my conscience. (recoded)		.75	.73	.74
When making a trip by car, it should burden climate and oil reserves as little as possible.		.80	.81	.80
Response efficacy	Explained variance	68.13	68.17	67.85
	Cronbach's alpha	.76	.76	.76
Buying a more fuel economical vehicle, I can effectively contribute to the protection of the climate.		.87	.88	.87
Buying a more fuel economical vehicle, I can effectively contribute to save oil.		.81	.78	.80
It doesn't matter what car I buy as it makes no difference regarding protecting our climate. (recoded)		.79	.81	.80
Problem awareness	Explained variance	51.60	51.77	52.56
	Cronbach's alpha	.81	.81	.82
People exaggerate the role of car traffic as the cause for climate change. (recoded)		.81	.80	.82
The change of the climate should not be dramatized. (recoded)		.78	.79	.79
People exaggerate the role of car traffic for oil consumption. (recoded)		.77	.79	.77
When thinking of the consequences of traffic on the climate, I am very worried.		.67	.66	.68
When thinking of how we deal with our oil supplies, I am very worried.		.64	.60	.64
I don't believe that oil depletion is as bad as often claimed. (recoded)		.62	.64	.63
Symbolic motives	Explained variance	51.26	49.42	50.19
	Cronbach's alpha	.68	.66	.67
It is important to me to drive a car which appeals to me.		.74	.71	.71
For me, the car has instrumental functions only. (recoded)		.74	.77	.76
To me, cars are very important.		.67	.60	.63
It does not matter to me which type of car I drive. (recoded)		.71	.72	.73
Evaluation of less power and size (attitudinal component)	Explained variance	63.56	60.26	61.33
	Cronbach's alpha	.71	.67	.68
Within car purchase, how do you evaluate a smaller car?		.76	.73	.75
Within car purchase, how do you evaluate a car with a less powerful engine?		.90	.88	.89
Within car purchase, how do you evaluate a car which accelerates less?		.72	.71	.70

Note. For the model variables: Cronbach's alpha (correlation coefficient for construct with 2 items) and variance explained by the indicators are presented. For the indicators: Wording and PCA-loadings on the corresponding factor are included.

Stated importance of fuel consumption. For the dependent variable importance of fuel consumption (with an ordinal response scale from 1 = not marked at all to 13 = decided at first) a mean score of 9.02, standard deviation of 3.76, and median of 10 result. This indicates, on average, a fairly high importance of fuel consumption within next car purchase.

CO_2 emissions of vehicles. The average (type-approval) CO_2 emissions of the respondents' most recently purchased vehicles have a mean of 186.7 g/km and a median of 181.0 g/km (min. = 107.0, max. = 344.9, *S.D.* = 40.52) which corresponds to the average of new car registrations in Switzerland in 2006 (*M* = 187 g CO_2/km, Median = 183.8). We cumulated the specific CO_2 emissions for all vehicles in a household built and bought since 2000 (cf. Section 3.2). These cumulated CO_2 emissions range from min. = 110.5 g for a household with one vehicle to max. = 1535.4 g for a household with seven vehicles bought since 2000. Of the other vehicles in the household, which were considered, 53.6% were also bought new. The average of cumulated CO_2 emissions is 319.8 g (*S.D.* = 183.6), the median is 264.9 g.

Table 4.3. Significant correlations of the psychological predictors (variables 1-7) and the respective dependent variable(s) (variable 8 for Analysis 1, variables 9-12 for Analysis 2) for Sample 1 (N_1 = 265, lower triangular matrix) and Sample 2 (N_2 = 302, upper triangular matrix) separately

Variables	1	2	3	4	5	6	7	8	9	10	11	12
1. Social norm	–	.14*	.29***	.18**	:20***	-.12*	n.s.		-.11*	-.14*	-.14*	-.16**
2. PBC	.17**	–	.28***	.32***	n.s.	n.s.	n.s.		-.25***	-.25***	-.25***	-.15*
3. Personal norm	.36***	.30***	–	.41***	.39***	-.31***	.34***		-.36***	-.34***	-.22***	-.32***
4. Response efficacy	.19**	.25***	.35***	–	.31***	n.s.	.23***		-.24***	-.20***	n.s.	-.18**
5. Problem awareness	.32***	n.s.	.44***	.28***	–	-.32***	.30***		-.21***	-.21***	-.13*	-.19**
6. Symbolic motives	-.21***	n.s.	-.29***	n.s.	-.29***	–	-.33***		.16**	.12*	.16**	.31***
7. Evaluation of less power and smaller size[a]	.23***	.18**	.33***	.19**	.33***	-.27***	–		-.32***	-.21***	-.15**	-.13*
8. Importance of fuel consumption	.19**	.15*	.27***	.13*	n.s.	-.26***	.13*	–	n.s.	n.s.	-.26**	-.20*
9. Proxy ABS								n.s.	–	.79***	.59***	.39***
10. Proxy SES								n.s.		–	.53***	.41***
11. Proxy HHT								-.26**			–	.45***
12. Proxy CUM								-.20*				–

Note. The dark shaded cells represent correlations between variable pairs which do not apply for the sample of the study. The light shaded cells represent the correlations of the dependent variable of Analysis 1 with those of Analysis 2 ($N \geq 126$, intersection of both samples). Usually, the Pearson correlation coefficient is given, except for the correlations with the ordinal variable importance of fuel consumption for which Spearman's rho was calculated. For the definition of the proxies see Section 3.2.

[a] Attitudinal component.

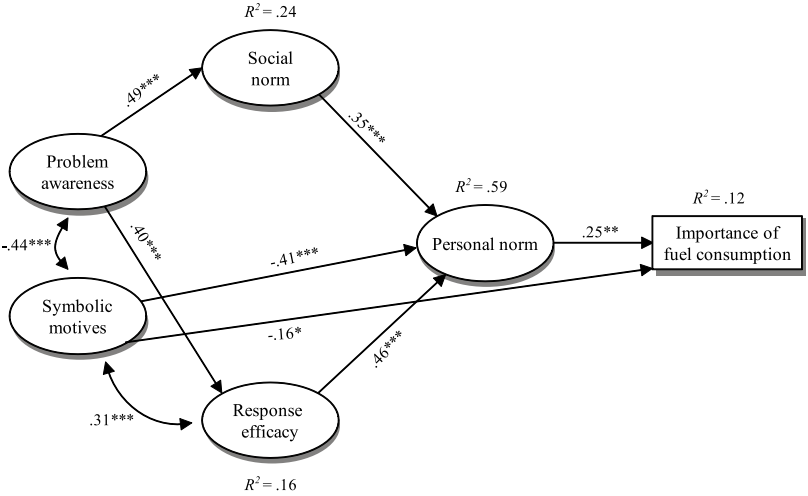
*$p \leq .05$; **$p \leq .01$; ***$p \leq .001$.

Correlation between all variables. Table 4.3 presents the significant correlations of the seven psychological variables and the respective dependent variable(s) for Sample 1 and Sample 2. In both samples, the significant correlations among the psychological variables are positive, except for symbolic motives. The height of most correlations between specific variables is comparable for the two samples, although some differences can be observed. In both samples, the correlations between personal norm and the other model variables are the highest. In Sample 1, only symbolic motives correlate negatively with the importance of fuel consumption; all other model variables, except problem awareness (no significant correlation), correlate positively with the dependent variable. The direction of the correlations are reversed for the dependent variables in Sample 2, the four behavioral proxies. This is in line with the expectation that importance of fuel consumption should be negatively correlated with CO_2 emissions within a person's actual car purchase behavior. However, for the overlapping subsample, which provides data on all dependent variables, this expectation is confirmed only for the behavioral proxies HHT and CUM, adjusting CO_2 emissions for household type. All four behavioral proxies correlate highly among each other in Sample 2. In comparison, proxy CUM deviates strongest from the single-vehicle proxies.

4.2 Influence of psychological variables on stated importance of fuel consumption (Analysis 1)

The assessment of the full theoretical model of psychological variables influencing stated importance of fuel consumption (cf. Figure 4.2) by means of the structural equation approach yielded the following goodness-of-fit statistics: $\chi^2 = 13.86$, df = 11, $p = .24$; *GFI* = .99, *AGFI* = .96, *CFI* = .98, *RMSEA* = .03. Although these overall results are already satisfactory, a closer look into the estimated coefficients reveals the need for some modifications.

Personal norm could be confirmed as a significant direct predictor of importance of fuel consumption, but we did not find a significant direct contribution of PBC and evaluation of less power and smaller size. As factors directly influencing personal norm self-efficacy, social norm, and symbolic motives could be empirically supported. However, problem awareness did not prove to directly influence personal norm besides its indirect influence via response efficacy and social norm.



$\chi^2 = 10.96$, df = 6, $p = .09$; *GFI* = .99, *AGFI* = .95, *CFI* = .94 , *RMSEA* = .06

Figure 4.3. Significant results of the estimated SEM to explain stated importance of fuel consumption within next vehicle purchase: significant standardized structural coefficients ($p \leq .05$ level), explained variances, and model fit indices.

With regard to an acceptable fit of the model, the modification indices for the modified model suggested two relations within the data which were not specified in the original model. First, a direct negative influence of symbolic motives on importance of fuel consumption was indicated. Theoretically, it seems reasonable that strong symbolic motives directly affect the importance of fuel consumption as consumers might be much more interested in other vehicle criteria. Second, the modification indices suggested a positive correlation of symbolic motives and response efficacy. That is, respondents with stronger symbolic motives tend to state more that a change of their purchase behavior would contribute to protect the climate or to save oil, and vice versa. Although one might, at first sight, have expected a negative correlation, this relationship makes sense according to the following reasons. For the time of the survey, we assume that consumers with strong symbolic motives attach importance to car size and power and are more likely to buy larger vehicles with bigger engines. It might be obvious that a change of their purchase behavior to more fuel economical vehicles would be effective to reduce fuel consumption. Thus, people with larger and more powered vehi-

cles might agree more than people with smaller and less powered vehicles that a change of their car purchase behavior would have an effect although they might be less willing to really change it due to stronger symbolic motives.

Hence, based on these cues and theoretical assumptions, we suggest an adapted model (cf. Figure 4.3) resulting from a few modifications to the original model: deletion of the non-significant predictors PBC and evaluation of less power and smaller size; deletion of the non-significant path from problem awareness to personal norm; specifying a direct path from symbolic motives to importance of fuel consumption; specifying a correlation between symbolic motives and response efficacy. According to the model fit indices depicted in Figure 4.3, the estimated structural model produced an acceptable fit to the data. However, the two direct predictors, personal norm and symbolic motives, explain only 12% variance of the stated importance of fuel consumption.

A regression analysis of the model variables on importance of fuel consumption confirms the SEM results: only the direct predictors personal norm and symbolic motives have significant influence and explain 11% variance of the importance ratings (cf. Table 4.4).

Table 4.4. Standardized regression coefficients β for psychological variables predicting (1) stated importance of fuel consumption within the next vehicle purchase (Analysis 1; $N_1 = 265$) and (2) to (5) various proxies of CO_2 impact of car purchase (Analysis 2; $N_2 \geq 288$)

	Analysis 1	Analysis 2			
Dependent variables / **Predictor variables**	**Stated importance of fuel consumption**	**Proxy ABS**	**Proxy SES**	**Proxy HHT**	**Proxy CUM**
Social norm	.07	.01	-.03	-.07	-.05
PBC	.04	-.16**	-.17**	-.23***	-.07
Personal norm	.18*	-.21***	-.22***	-.10	-.19**
Response efficacy	.04	-.04	-.01	.08	-.08
Problem awareness	-.07	-.04	-.08	-.04	-.01
Symbolic motives	-.19	.01	-.01	.09	-.26***
Evaluation of less power and smaller size (attitudinal component)	.02	-.23***	-.10	-.07	.06
R^2	.11	.21	.16	.11	.17

Note. For the definition of the proxies see Section 3.2.
*$p \leq .05$; **$p \leq .01$; ***$p \leq .001$.

4.3 Influence of psychological variables on actual fuel consumption (Analysis 2)

The results of regression analyses of the psychological predictors on the various behavioral proxies are displayed in Table 4.4. The regression on the dependent variable of Peters, Scholz, and Gutscher (2008), absolute CO_2 emissions of the most recently purchased vehicle (proxy ABS), is in line with their SEM results: Only for the direct predictors evaluation of less power and smaller size, PBC and personal norm a significant influence was revealed. Together, they explain 21% variance of proxy ABS.

With regard to the regression results for the other behavioral proxies, the following differences can be observed. Whereas PBC is significant for all single-vehicle proxies, it has no significant influence on proxy CUM. An influence of personal norm can be observed for all proxies except for proxy HHT. Evaluation of less power and smaller size does not show significant influence on the various proxies besides the abovementioned one on proxy ABS. Finally, the predictor symbolic motives only gains significance for proxy CUM.

Hence, the whole picture shows consistent results for the predictors of the intentional variable and the behavioral proxy CUM. As well, the results for the predictors of the single-vehicle proxies, ABS, SES, and HHT, show a partly similar pattern.

The variance explained by the psychological predictors is highest for proxy ABS (R^2 = .21). Proxy SES as well as proxy CUM follow with a moderate explained variance (R^2 = .16 and R^2 = .17, respectively), whereas explained variance is lowest for proxy HHT (R^2 = .11).

5 Discussion and conclusion

Research goals of this paper were to (1) obtain insights into the nature of the relevant psychological constructs, (2) explore consequences of various proxies of environmental behavior and obtain hints for the design of such proxies, and (3) gain practical implications for a better promotion of fuel-efficient vehicles. The first two points are discussed in this chapter. Practical implications are presented in the last chapter.

5.1 Insights into the nature of the psychological constructs

When comparing Analysis 1 and Analysis 2, besides the finding that intention is explained to a lower degree by a set of psychological variables than behavior, questions are raised by the different effects of evaluation of less power and smaller size, PBC, symbolic motives and social norm. In a first step we compare the final SEM model of Analysis 1 (cf. Figure 4.3) with the suggested model of Peters, Scholz, and Gutscher (2008) (cf. Figure 4.1).

Within Analysis 1, a slightly adapted and simplified model could be suggested which reached an acceptable model fit. However, only 12% variance of the dependent variable are explained. It is remarkable that intention is not explained by the psychological variables to a higher degree than the behavioral proxies (for common findings, cf. Section 2.3). The importance of fuel consumption within the next vehicle purchase is expressed mainly according to an inner feeling of obligation (personal norm) and inhibited by symbolic motives. In contrast, behavioral control to purchase a vehicle consuming less fuel and attitudinal aspects (evaluation of less power and smaller size) seem to be hardly considered and, thus, are not able to reach significant influence. Response efficacy and a supportive social norm appear to be relevant preconditions for the personal norm. They also fully mediate the influence of problem awareness on personal norm. Symbolic motives have a negative influence on personal norm.

However, according to the results of Peters, Scholz, and Gutscher (2008), when it comes to car purchase, besides personal norm the evaluation of less power and smaller size, often associated with more fuel economical vehicles, and PBC gain significant influence. Together, the direct predictors could explain 30% variance of the CO_2 emissions of the respondents' most recently purchased vehicles which is considerably more than the variance explained by the model explaining intended car purchase. As factors of indirect influence, the same variables are relevant for intended and real car purchase, except social norm, which loses significance for the case of actual car purchase.

In our view, a first explanation for the differences can be ascribed to the fact that the next vehicle purchase of the respondents is seldom in the nearest future, i.e., the purchase situation as well as the corresponding decision process is usually still rather vague and not tangible. Psychological constructs can be differentiated according to their closeness to behavior. That is, constructs which are very close to behavior exert direct influence whereas more basic psychological constructs present prerequisites without direct impact.

They need to be mediated by the behaviorally closer constructs. Intention is usually regarded as a construct very close to behavior (cf. Ajzen, 1991). However, for behaviors conducted in rather long intervals of time, a measured intention at a given time may still be rather vague.

Thus, though we encouraged the respondents to imagine buying their next vehicle within the next weeks, we might have assessed an intention which is not very close to behavior. This would imply that attitude and PBC, which are assumed to be close to behavior, might not yet show an influence on intention at a time when this behavior is in fact still far away. People may rather draw on their personal and social norms when rating their intention.

A different and separate influence of PBC on behavior is still in line with Ajzen (1991). Respondents may intend to purchase a more fuel economical vehicle, but they may not always have the necessary information. This might less effect intention but more the actual purchase behavior, if inappropriate heuristics are applied in the purchase decision process. For instance, many consumers assume that fuel consumption varies only marginally within vehicle size class (Boardman et al., 2000).

Moreover, many consumers might not be aware that fuel-efficient vehicles need not be smaller and that nowadays, even smallest engines have (more than) sufficient power to safely overtake other vehicles when necessary or to climb the usual uphill slopes. Thus, as indicated by the effect of evaluation of less power and smaller size on behavior, but not on intention, consumers intending to consider fuel consumption might refrain from choosing the smallest (though sufficiently powered) engines and instead regard a middle-sized engine as reasonable choice.

5.2 Methodological arguments for the results

From a methodological perspective, the strong influence of personal norms on stated importance of fuel consumption and the irrelevance of PBC and of evaluation of less power and smaller size might indicate a certain influence of socially desirable answering. This should not affect the dependent variables used in Analysis 2 (vehicle data).

In principle, another critical aspect might be the time lag between the statement of the dependent variable (Survey Wave 1) and the assessment of the psychological predictors (Wave 2). However, it cannot explain that less variance is explained for intended compared to actual car purchase. In fact, the time lag between the purchase of the vehicles in question and the assess-

ment of the psychological variables (Analysis 2) might often be even larger than the one-year time lag affecting the associations within Analysis 1. But the different time foci of the two analyses could be an explanation for different results: Whereas with the dependent variable stated importance of fuel consumption, the respondents were asked about *future intended behavior*, the characteristics of purchased vehicles reveal *past actual behavior*. Operationalization of the respective dependent variable is also of importance. The variables of Analysis 2 use data on CO_2 emissions of recently purchased new vehicles and, thus, factually inform about actual buying behavior. In contrast, the intentional measure within Analysis 1 is less factual.

5.3 Conclusions about possible behavioral proxies

Regression analyses on alternative behavioral proxies (Analysis 2) show interesting differences as well as similarities between the significant predictor variables. The degree of variance explained by various psychological factors is highest for proxy ABS (significant predictors: evaluation of less power and smaller size, personal norm, PBC). Compared to the meta-analytical results of Armitage and Conner (2001) for objective measures of behavior (R^2 = .21), it seems to be in an acceptable range. However, all adjusted proxies are only moderately explained by the psychological variables. With an adjustment of CO_2 emissions for socio-economic status (proxy SES), PBC and personal norm remain of significant influence. However, evaluation of less vehicle power and smaller size is no longer significant. For CO_2 emissions adjusted to household type (proxy HHT), only PBC has still significant explanatory power. In contrast, cumulated CO_2 emissions of vehicles in the household bought since 2000, adjusted by household type, (proxy CUM) can be predicted best by symbolic motives and personal norm, which have also proven relevant to the intentional proxy.

Across all adjusted proxies, evaluation of less vehicle power and smaller size loses explanatory power. An explanation might be that households of smaller size or lower socio-economic status, which tend to have lower absolute CO_2 emissions, have a more positive attitude towards less vehicle power or smaller size. Such households also tend to have lower income, and smaller engines and smaller size both reduce vehicle costs.

The results concerning the intention-behavior-relation deliver further hints that an adjustment for consumers' living situation might be feasible to evaluate their car purchase behavior: No significant correlation could be ob-

served between proxy ABS and stated importance of fuel consumption. This corresponds to the results of Klocke (2002b). Whereas the intentional proxy does not correlate with the behavioral proxy SES as well, it is significantly related to both household type-corrected proxies, HHT and CUM. Thus, compared to results in literature (cf. Section 2.3), the intention-behavior relation seems underestimated particularly when applying the behavioral proxies ABS and SES. The intention-behavior relation is higher if household type is accounted for. Such a proxy might be feasible, as it better considers needs and constraints of consumers with larger households.

However, the adjustment chosen for proxy SES is based on vehicle data (shadow) and not on household data (e.g., income and education), as it is the case for the household type adjustment (proxies HHT and CUM). Hence, proxy SES might not fully cover the influence of socio-economic status.

Comparing the results for the proxies considering only the last vehicle purchase (proxy ABS, SES, and HHT) vs. more vehicle purchases (proxy CUM), the same predictors have proven significant for the intentional variable and for the behavioral proxy CUM, while for the other behavioral proxies differences in the relevant predictors were observed. A reason might be that the other proxies of past behavior capture single acts of behavior which are not necessarily representative for general purchase behavior. For multi-car households a car might have been selected for the single-vehicle proxies which consumes less fuel than the average vehicle of the household. Moreover, the consistencies are observed between the predictors of intention and the predictors of proxy CUM, capturing vehicle purchases up to 5.5. years ago, indicates that the determinants underlying car purchase behavior are rather stable over time.

Thus, for CO_2 emissions within car purchase behavior which is influenced by household type and socio-economic status, a proxy adjusted for household type and considering other vehicles in the household seems best suited to evaluate purchase behavior of different groups. In general, the different consequences resulting from a chosen behavioral proxy underline a careful selection as important.

6 Practical implications for the promotion of fuel-efficient vehicles

For a better promotion of fuel-efficient vehicles, the factors proven as relevant for both the *intention* to consider fuel consumption in the next vehicle purchase and its actual implementation into *behavior* should be considered. Regarding intention, *personal norm* and *symbolic motives* are of direct influence. *Response efficacy*, *social norm*, *problem awareness* and again *symbolic motives* have proven as relevant preconditions. Thus, ensuring that consumers are aware of the problems related to fuel consumption would support the development and activation of a respective personal norm. However, problem awareness has only a moderate effect on intention. Without the mediating effect of other variables, consumers will not change their behavior. It is crucial that consumers really link their own purchase decision to these problems, i.e., that they are aware of the consequences of their behavioral options. This indicates the need for informational components of measures which should be designed in a concrete and vivid way. As well, it is important to develop and strengthen a social norm to support the personal norm to buy a more fuel economical. For example, financial incentives could emphasize the social desirability of purchasing fuel-efficient vehicles. Moreover, it is important, that people perceive the purchase of fuel-efficient cars by respected persons or institutions (i.e., by models). Here, the public sector can take a leading role and make fuel efficiency a prominent selection criteria for its car fleets.

Considering the influence of symbolic motives on both personal norm and intention, it is important to accelerate the shift of symbolic values from traditional characteristics such as car size and power to fuel efficiency. Fuel efficiency should be actively promoted as a popular feature which is compatible with other consumer needs. Fuel efficiency can gain in popularity by linking it to vehicles with intelligent technology, be it optimized conventional technology or new alternative technology.

However, in order to ensure the actual translation of this intention into action, measures should also account for consumers' *attitude* towards more fuel-economical vehicles and their *perceived behavioral control*. People should be better informed that such vehicles do not necessarily need to be smaller and that all vehicles have sufficient power to safely overtake other vehicles and to climb slopes.

Information and prompts, such as fuel efficiency labels, should help consumers to better identify fuel-efficient vehicles. Providing consumers with a baseline that accounts for their living situation should increase their motivation to do something. Thus, for labeling fuel-efficient vehicles and designing incentive schemes, a relative approach which relates fuel consumption to car size would be recommendable (see Peters, Mueller, et al. (2008) for an analysis of absolute vs. relative designs of incentive schemes). In general, various measures starting at different relevant factors and supporting each other should be combined for a better promotion of fuel-efficient vehicles.

Chapter V

General discussion and conclusions

1 Summary

Consumer adoption of fuel-efficient cars is required to reduce energy consumption in the road transport sector. Today, consumers seem to be well aware of the problems related to the energy use of vehicles. Moreover, fuel-efficient vehicle alternatives are available in all car size categories and price classes. Many people state that fuel consumption is important to them; however, intention to consider fuel economy in car purchase is often not implemented into effective action. Published studies which analyze psychological factors and processes which play a role in the choice of fuel-efficient vehicles are rare. Models of car choice behavior, which are also applied in the evaluation of measures aimed at changing car choice behavior, predominately concentrate on sociodemographic factors. However, in order to improve the promotion and thus adoption of fuel-efficient vehicles, a better understanding of the underlying psychological factors is important.

The main objective of the present dissertation was to close this knowledge gap by identifying psychological factors that influence fuel economy through influencing consumers' car choice. Therefore, a model drawn from literature on environmental behavior and combining relevant psychological theories (theory of planned behavior and norm-activation model) was adopted. By means of a quantitative survey, the psychological variables of this model, the car purchase behavior, and the likelihood of acceptance of specific measures to change this behavior were assessed. Three studies analyzing this data combined with data of the Swiss vehicle market show different relevant aspects of car purchase behavior.

The first study (Chapter II) pointed out the complexity of the vehicle market, consumer heterogeneity, and consequences of fiscal measures to promote the purchase of fuel-efficient vehicles. This was achieved by analyzing possible effects of feebate schemes to promote fuel-efficient vehicles on car purchase behavior. The results point to a dilemma inherent to such measures of simultaneously addressing more consumers while limiting counteracting effects. This dilemma emerges from the complexity of the vehicle market and in the heterogeneity of consumer groups. A central recommendation for the development of effective measures is to differentiate consumer segments according to relevant psychological factors pertinent to the purchase of fuel-efficient vehicles.

A second study (Chapter III) aimed to identify such factors. To this aim, we tested the abovementioned model of psychological factors with regard to

their role and interplay when influencing consumers' actual purchase of fuel-efficient vehicles. The results indicate that CO_2 emissions of the respondents' vehicles depend directly (1) on the valence of less power and smaller size which the respondents commonly associated with fuel-efficient vehicles, (2) on their personal norm to buy a fuel-efficient vehicle, and (3) on their respective perceived behavioral control. Important preconditions for these predictors, in turn, are (1) the awareness of problems such as climate change or fossil fuel scarcity, and (2) perceived response efficacy of one's own behavior to do something about these problems. In contrast, symbolic motives inhibit the activation of a personal norm and influence the valence of less power and size negatively.

A third study (Chapter IV) compared psychological factors influencing fuel consumption and CO_2 emissions within intended vs. actual car purchase. The results indicate that stated importance of fuel consumption is mainly expressed according to an inner feeling of obligation and is inhibited by symbolic motives. No significant effects could be observed for perceived behavioral control and valence of less vehicle power and size, which have been proven to significantly influence CO_2 emissions in actual car purchase in Study 2. In theoretical regard, the differences between factors explaining this intentional variable vs. factors explaining the behavioral variable of Study 2 provide deeper insights into the psychological constructs. Mainly, they are founded in the nature of the various factors, i.e., in their closeness to behavior.

Comparisons of various proxies of a person's car purchase behavior show that results differ considerably with the choice of a proxy. Absolute proxies which do not consider a person's living situation underestimate pro-environmental car purchase behavior of households of larger size and higher socio-economic status. Thus, in order to reveal environmental behavior appropriately, a behavioral proxy should be chosen carefully and with regard to the specific characteristics of the respective behavior. This is important for the evaluation of measures aimed at changing behavior which address various groups that differ considerably in relevant resources and needs. With regard to car purchase, an adjustment for household type while also considering other vehicles found in the household seems to match differences in purchase behavior due to consumers' living situation better than proxies which (a) evaluate CO_2 impact of a person's purchase behavior absolutely, (b) were designed to adjust for socio-economic status of a person's household or (c) consider only the most recently purchased vehicle. Finally, with regard to a

successful promotion of fuel-efficient vehicles, practical implications were drawn from the results.

The main results of these studies are discussed in more detail at the end of each chapter. In this chapter, critical aspects of the applied methods are first discussed. Subsequently, an outlook highlighting theoretical as well as practical implications of how to proceed given the results is provided. Finally, further research perspectives are presented.

2 Evaluation of the applied method

The data for this thesis was obtained from a survey which was conducted in two waves in an interval of one year. This design was chosen to reduce the respondents' burden in light of the extensive amount of questions motivated by the copious research interests found within the project. In addition, the time interval of one year was chosen in an effort to collect revealed preference data of new vehicles purchased in this interval.

In general, the survey method has proven valuable for the measurement of psychological constructs such as norms, beliefs and attitudes. It also has the advantage of allowing the collection of detailed data on the vehicles owned by the respondents to assess actual purchase behavior.

However, the elicitation of valid responses on the importance of various decision criteria might be difficult by means of a survey. We aimed to encourage and oblige the respondents to think more about the criteria which were of greater importance to them by applying a ranking approach in which they could not rate all items as equally high. We also regard this technique as a useful means to discourage answers based solely on what is socially desirable. However, the validity of the operationalization of intention to buy a fuel economical vehicle within the next car purchase through the stated importance of fuel consumption in the next car purchase might still be critical.

In general, an alternative and useful method to gain evidence on the importance of various decision criteria is through experiments. For instance, the Mouselab methodology (Payne, Bettman, & Johnson, 1988) seems promising as it allows the study of the order in which available information on decision criteria is retrieved, along with the choices following from this information search. However, this method might be problematic with regard to its validity as well as participants might be encouraged by the experimental design to apply a decision process which they do not adhere to in reality.

For example, the availability of specific information and the explicitly stated task to access relevant information in order to make an informed decision might induce participants to refrain from applying simplistic rule-of-thumbs and retrieve other or more information than they would in reality.

To return to the specific design of our survey, the first survey wave measured, among other things, the importance of various decision criteria and collected data on the vehicles owned by the respondents' households as well as sociodemographic data of the respondents. The second survey measured psychological factors as well as changes in the vehicle stock of the household.

Accordingly, the data used for this thesis only represents cross-sectional correlational data which does not reflect causality, as each survey measured different aspects. For the consolidation of our causal interpretations, it would be insightful to analyze longitudinal data or data collected according to an experimental design.

An advantage of this survey design was that in the first wave we could avoid a focus on environment in order to discourage answers based solely on what is socially desirable. However, the time interval of one year between the two survey waves might be critical with regard to the associations between the psychological variables measured in the second wave and the intentional variable assessed in the first wave as changes in the psychological variables could not be controlled over the time period. However, this argument applies not only to the associations between the psychological predictors and the intentional variable stated importance of fuel consumption, but applies even more to the associations between the predictors and the CO_2 emissions of actually chosen vehicles, since the vehicles in question were bought up to 3.5 years before the survey (5.5 years if other vehicles in the household are considered). We assume that the psychological predictors have shown a certain stability over time considering the context of the survey. One could say that the survey was conducted at an early stage of public attention towards topics related to fuel consumption of vehicles. The two survey waves were conducted in the summers of 2005 and 2006 when the oil price was still below 70 US-$/barrel (2005) and 80 US-$/barrel (2006). In contrast, it rose dramatically to almost 100 US-$/barrel in 2007. Additionally, part one of a series of reports of the IPCC's fourth assessment (IPCC, 2007b), which considerably increased public attention to and media coverage of climate change, were not yet released at the time the survey was conducted.

The consistencies between intention to consider fuel consumption within the next vehicle purchase and actual vehicle purchases up to 5.5 years previously that were observed in Study 3 (Chapter IV) support our assumption that the determinants underlying car purchase behavior have been rather stable in the years before the survey. They might change with changing conditions, e.g., intensified measures to promote fuel-efficient vehicles and rising problem awareness in the public.

However, the associations between intention and the psychological constructs to explain environmental behavior on the one side and the relevant characteristics of vehicles owned by the household on the other side may have been influenced by the different levels on which these variables were measured (cf. Gatersleben, Steg, & Vlek, 2002). The choice of the specific vehicle is likely influenced by other household members and not only by the person which filled out the questionnaires. In order to adjust the measurement levels for the dependent variables and the psychological variables, we asked the person (1) who was likely to buy the next car, or (2) who had bought the last car (or was significantly involved within the decision process), or (3) who used to drive the most to fill out the questionnaire. Another approach to this problem could be measuring the psychological constructs at the household level, i.e., to collect these data for each household member. However, this approach may result in very long questionnaires and increase the risk of missing values and low response rates.

Generally, we are convinced that surveys represent a useful method with regard to studying psychological factors influencing fuel consumption and CO_2 emissions within car purchase. In order to use the advantages of this method but compensate for its weaknesses, a combination with experiments could be developed and tested in further studies.

3 Relevance of the results for further research and practice

In conclusion, this thesis provides various insights into the role and interplay of psychological determinants influencing car choice behavior with regard to fuel consumption and CO_2 emissions. How can these results be used in further research and practice?

With regard to research, this thesis provides a basis for an enrichment of traditional vehicle choice models through psychological variables. For in-

stance, the weighting of fuel consumption as a decision criterion could be additionally explained and improved on by latent psychological variables. Moreover, our results could be used to create a differentiation of consumer groups based on relevant variables which might also prove helpful for practical purposes.

With regard to practical implications, the results on relevant factors influencing the purchase of fuel-efficient vehicles indicate starting points for establishing effective interventions. As outlined in Chapter IV, a promotion of consumers' intention to consider fuel consumption in the next vehicle purchase should ensure that they are aware of the problems related to fuel consumption. Further, it should support the link between the consumers' own purchase decision to these topics, i.e., that they are aware of their behavioral options to do something about these problems. The public sector should take a leading role in strengthening social norms which support the intention to consider fuel consumption and in promoting fuel efficiency more actively as a popular feature of symbolic value. In order to ensure the actual translation of intention into action, it is decisive to better inform people that such vehicles do not necessarily need to be smaller or that, today, even the vehicles with the smallest engines have (more than) sufficient power to safely overtake other vehicles when necessary or to climb the typical uphill slopes. Moreover, information and prompts such as fuel efficiency labels that help consumers to better identify fuel-efficient vehicles might be effective. Financial incentives combined with an effective information and marketing campaign could be a helpful instrument used to gain consumers' attention and support a change of the relevant psychological factors and finally of car purchase behavior (cf. also de Haan et al., 2007). In general, various measures based on different relevant factors and supporting each other should be combined.

4 Future research perspectives

Although we captured various relevant influences on car choice by including the constructs of TPB and NAM as well as symbolic motives, other potential influences are left for future research. For example, it would be interesting for further studies to include the effect of habits or analyze the influence of contextual conditions, e.g., the influence of the salesperson or of time pressure within the decision process. Moreover, in order to be able to

evaluate the effective contribution of psychological variables for models forecasting fuel consumption and CO_2 emissions in car purchase, the actual integration of psychological variables into such models seems necessary.

With regard to further advancing such models, it could be useful to study the elaboration of the decision process. In contrast to traditional model approaches which usually apply one decision model differentiating consumers through criteria coefficients, we suppose that there are fundamentally different decision models which vary in the effort spent in the decision process and in the likelihood with which they are adopted by different consumer segments and under specific conditions. On the one hand, there may be models which correspond to a multi-attribute utility model. On the other hand, there may be simple heuristics such as buying a certain vehicle make and model which is next in size to the one owned before. Following the elaboration likelihood model by Petty and Cacioppo (1986), which explains how people can be influenced by information under different conditions, we assume that the way people make their choice for a certain car depends on certain parameters like motivation, ability, and possibility to search and process information.

Moreover, this study is limited mainly to private car buyers. Corporate customers are neglected. As they represent a significant part of the market and their decision process might differ with regard to constraints or incentives promoting the purchase of fuel-efficient vehicles, it would be useful to extend the research to this customer group.

With regard to estimating the effects of incentive schemes by means of vehicle choice models, it seems important to incorporate mechanisms which are relevant to the perception of money. We hypothesize that people do not perceive money according to the traditional economic approach. Instead, we assume that relevant phenomena of Prospect Theory (Kahneman & Tversky, 1979, 2000) have decisive impact on how people perceive monetary incentives. Therefore, the psychology of money in the context of car purchase should be studied in order to analyze the impact of those incentives. This part was touched on in the project in which this thesis was embedded (cf. Mueller & de Haan, 2009).

Finally, when the theoretical basis of explaining the purchase of fuel-efficient vehicles will have been consolidated, it will be valuable to evaluate and compare the effectiveness of measures (or of combinations of measures) which aim at changing car purchase behavior.

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Appendix

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Reducing energy consumption in road transport through hybrid vehicles: investigation of rebound effects, and possible effects of tax rebates

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Abstract

Hybrid powertrains are considered to be a promising method to raise the overall fuel efficiency of passenger cars. They are predicted to enter the automobile markets in increasing numbers in the near future. This paper investigates 2 aspects relevant to the promotion of hybrid vehicles as part of an energy reduction strategy. First, are hybrid cars accompanied by rebound effects, which counteract their increased fuel efficiency? Second, do tax rebates indeed lead to higher sales numbers? We present results from a survey conducted with all 367 buyers of hybrid second-generation Toyota Prius in Switzerland in the first 9 months after market entry (response rate, 82.6%). As control group, questionnaires were also sent to 250 Toyota Corolla (61% returned) and 250 Toyota Avensis (52%) buyers. Among other items, the surveys asked for the car being replaced, if any. Main results are that the increase in car size for hybrid car buyers was lower than both, the market trend and the control group. Increase in car size was lower for hybrid car buyers than for both control group and market trend. 6% of hybrid car purchases did not replace a previously owned vehicle (control group 3%, $P = 0.05$), the Swiss market average being 20%. Hence rebound effects could be identified neither for vehicle size nor for vehicle ownership. As an energy policy measure, hybrid vehicles are eligible for tax rebates in parts of Switzerland. We found evidence that these tax rebates indeed lead to significant higher sales. We present a rough cost estimate of such tax rebates as CO_2 abatement policy tool.

Keywords: Hybrid cars; Direct rebound effect; Survey; Fuel consumption; Vehicle size; Car ownership; Vehicle transaction; Energy-efficiency; Early adopters; Car ownership tax; Toyota Prius; CO_2 abatement cost

1. Introduction

The continuing increase in energy consumption, the mid-depletion point of conventional oil and of the re-concentration of crude oil production in the Near East will compel industrialized as well as developing nations to make more efficient use of energy [1]. Technological improvements still are the most important source for energy savings [2,3]. As there is no doubt that the challenges will increase within the next few decades, and as the re-investment cycles of the passenger fleet, the production capacities, and infrastructures have to be considered, early actions and long-term perspectives by governments and technology producers become increasingly important. The transportation sector accounts for 21.8% of total primary energy consumption worldwide in 2000, and will account for ca. 34% in 2050 (OECD countries: 28.1% and 40%, respectively) [1]. In the European Union (EU), road transport at present is the second-largest sector of energy consumption, but is one among the fastest growing sectors regarding CO_2 emissions, with an increase of 20% between 1990 and 2000.

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Various policy measures have been introduced in many countries, and are considered for implementation in other countries, to reduce CO_2 emissions from individual road transport. For this there are 3 main routes: (i) by reducing demand, i.e., the number of passenger kilometers; (ii) by reducing the energy intensity per passenger kilometer; and (iii) by reducing the CO_2 intensity of energy. The latter can be achieved by the use of nuclear, alternative fossil (diesel and natural gas), or renewable energy sources; it is not the topic of the present paper.

Demand reduction, on the one hand, can be achieved with higher fuel taxes (energy tax or carbon tax), toll, congestion tax [4], road pricing [5], and also by subsidizing mass transit (public transport). Since owning a vehicle is a good predictor for vehicle use, reduction in the number of vehicles (through increases in sales tax or ownership tax) is often also regarded as an effective measure to reduce induced demand.

Reduction of energy intensity per passenger kilometer, on the other hand, can be achieved by the following:

- increasing occupancy (promotion of car-pooling by privileges, e.g. high-occupancy vehicle lanes and high-occupancy/toll lanes [6,7]);
- reduction of energy-intensive traffic conditions like congestion [8,4] and high-speed driving above 90–100 km h^{-1};
- reduction in car size, and/or engine downsizing;
- improvements to the internal combustion engine itself, or switch to other concepts like fuel cells [9];
- increasing the overall efficiency of the car: reduction of energy consumption by auxiliaries, reduction of drag, improved tire pressure, synthetic lube oil, etc.; and
- the use of hybrid powertrains [10] to recuperate braking energy.

Hybrid powertrains are energy-efficient since in addition to recuperation, they also allow for an idle-off strategy, a higher share of engine modes with high thermodynamic efficiency, and for engine downsizing (due to short-term additional power from the electric engine). Therefore, hybrid powertrains are considered to be a promising option to decrease fuel consumption by passenger cars [11]. The few hybrid car models currently available have increasing sales numbers, and most large car manufacturers have announced hybrid cars for the coming years. In 2004, 8 vehicle models utilizing hybrid-electric powertrains were on the U.S. market and had sales of 88,000 units (0.52% market share) [12] forecast that by 2011, 38 models will total to 535,000 sold units and 3% of U.S. sales.

Hybrid cars are an energy-efficient technology, however, from a macroeconomic point of view the introduction of more efficient products is often accompanied by rebound effects (also called take-back effects). If a product or service becomes more efficient (regarding energy use or the use of some other resources), it will also become cheaper: higher energy-efficiency in production would mean lower sales price and hence increased demand. Higher energy-efficiency in the use phase would mean lower operation costs and hence increased demand. This counteracts the positive effect of increased efficiency. The definition, identification and quantification of rebound effects are areas of ongoing research [13,14]. Generally, 3 different rebound effects might be induced [2]: increased demand for the same service as it has become cheaper (direct rebound effect), increased demand for other services as money (i.e., purchasing power) has become available (indirect rebound effect; also called secondary rebound effect), and structural effects on larger parts of the economy due to changed demand, production and distribution patterns (macro-scale rebound effect; also called economy-wide or tertiary rebound effect).

For example, if the energy efficiency of a car is increased by technological innovations, 100 km can be driven with less fuel and hence at a lower cost. This lower cost should have the consequence that people demand more ''car services'', i.e., drive more often, and/or drive longer, and/or drive with larger cars. Identification of occurrence, and, if present, quantification of rebound effects are generally not straightforward. Most work has been done on the effects of the introduction of energy-saving technologies, e.g. space heating [15].

Rebound effects induced by costs savings were the first to be investigated and originated in economics, especially energy economics. In close analogy, also the reduction of socio-psychological costs of ownership might be regarded as possible driver for rebound effects. For example, it may not be the financial but the socio-psychological cost-of-ownership (due to neighborhood pressure, norms of a peer group, etc.) that prevents some people from buying sport-utility vehicles (SUVs). However, this could change as soon as SUVs with hybrid powertrain enter the market. Of course, for other people with different cultural and/or social backgrounds, owning an SUV might instead be positive (e.g. as an expression of wealth), but this is not likely to be affected by the market entry of hybrid SUVs.

The present paper aims at identifying the occurrence, and, if present, at quantifying 2 kinds of direct rebound effects that could possibly occur when buying hybrid cars: (i) people could tend to switch from small and/or already fuel-efficient cars to the new hybrid car, and (ii) average household vehicle ownership (HVO) could increase if people either tended to purchase the hybrid car as an additional household vehicle without disposing of an already owned vehicle, or because the availability of hybrid cars could make the decisive difference for a household to purchase a vehicle for the first time. In addition, we analyze the impact of car ownership tax rebates on the number of hybrid vehicles sold.

The paper is structured as follows. Section 2 presents the research objective and research questions. The surveys are introduced in Section 3. Section 4 investigates the presence of the first rebound effect as mentioned above, possible above-average increase in car size for hybrid car buyers. Section 5 analyses car transaction behavior, and investigates the presence of the second rebound effect, possible above-average increases in vehicle stock for hybrid car buyers. Section 6 provides an estimate of efficiency of car ownership tax rebates for hybrid cars. Section 7 presents our concluding remarks with regard to the rebound effects under investigation, and consequences for future research.

2. Possible side effects of hybrid car purchases

2.1. Possible increase in car size

The first objective of the present study was to investigate whether the following so-called direct rebound effect can be detected, and, if so, can be quantified: an above-trend increase in car size for hybrid vehicle buyers (i.e., the new hybrid vehicle is larger than the average previously owned vehicle that has been disposed off). If the use of a car costs less, people will use more car services. This is called the direct rebound effect (e.g. [2,9,16]), sometimes also called take-back effect.

An increased demand for ''car services'' can mean that consumers either use the car *more often* (more trips, e.g. instead of public transport), or *longer* (driving longer trips, etc.), or that they use *a larger car* (here, larger might be either an increase in size, or an increase in relative power, or both). A highly fuel-efficient car will have lower operational costs, comparable mainly to cars which are much smaller than the hybrid vehicle in question. So it could be expected that a certain percentage of hybrid vehicle buyers trade in a car belonging to a smaller segment (smaller car size). Though this might be intuitive, it should be noted that there is no economic driver for such a behavior: the sales price for a hybrid vehicle is higher than for a vehicle with conventional powertrain.

The surplus sales price of hybrid vehicles at present seems to be chosen by the manufacturer such that it compensates partly if not completely for the future fuel reduction. In the U.S., the Prius sells at EUR 3300 (using a USD/EUR exchange rate of 1.06) more than the Toyota Corolla (1.6 l VVT-i engine, Linea Sol, 5-door, automatic transmission, hatchback), which is not fully paid back over a vehicle lifetime of 250,000 km at current U.S. gasoline prices [17]. In Switzerland, where fuel prices (EUR 0.9–1.0 per liter) are higher than in Northern America but lower compared to surrounding European countries, surplus price is EUR 4800, which does pay back after ca. 150,000 km, which is the average vehicle lifetime in Switzerland. In Finland, where fuel prices are EUR 1.3 per liter gasoline, the price difference (before adding the Finnish car acquisition tax of almost +100%) is EUR 8000, which does pay back after ca. 180,000 km. So the price difference seems to have been set market-specific, compensating for expected reduction of (market-specific) fuel costs over the vehicle's (market-specific) lifetime.

In the absence of an economic driver for a possible rebound effect, de Haan et al. [16] introduced the concept of a socio-psychological driver that might still be present. Owning a car is associated with socio-psychological ''costs of car ownership'', which would be reduced in the case of a hybrid vehicle, generally being accepted as an environmentally friendly technology.

Another kind of socio-psychological reason could be that not all cost factors are perceived equally. It is generally accepted that car drivers tend to overweight fuel costs, but to underweight running costs (lube oil, tire replacements, repairs, etc.), car ownership taxes, and investment costs. This asymmetrical cost perception might lead individuals to purchase a hybrid vehicle out of quasi-rational cost reasoning where in fact the economic analysis would suggest to do otherwise.

We adopt empty vehicle weight (curb weight) as surrogate for ''car size''. For roughly the last 20 years, average empty vehicle weight of new car registrations has increased in Europe (including Switzerland) and Northern America. A rebound effect can only be considered as present if an increase in empty vehicle weight (defined as the weight of the new car minus the average weight of previously owned vehicles which are replaced by a new car) is higher than this general trend.

2.2. Possible increase in vehicle ownership

The second aim of the present paper is the detection, and, if present, quantification of a second direct rebound effect: an increase in average household vehicle ownership (HVO), i.e., that hybrid vehicles more often than conventional cars serve as an additional vehicle, thereby increasing the number of vehicles owned by a given household.

Again, as for possible increases in car size, there of course is no economic driver for any increase in car ownership due to the mere presence of hybrid vehicles on the market, as hybrid vehicles by construction are at least as expensive as conventional cars. So we should expect that if the above rebound effect is present, the reasons will be of socio-psychological nature. Possibly the introduction of the Toyota Prius as the first fully functional hybrid vehicle leads to surplus purchases in those population groups for which owning a second (or third, etc.) car is connected with socio-psychological costs, which could be lower for fuel-efficient vehicles like hybrids.

Even though it is simple to conclude for an entire population whether average HVO has increased or not, this same question is hard to answer for a sample of new car buyers that answered a mail-back survey. In any population, young households or individuals will at sometime purchase a vehicle for the first time. And in correspondence, old households or individuals will at some point in life discard their last vehicle. So seen from the viewpoint of an individual, there is always a first-time car purchase at first, followed by several car replacements, and possibly accompanied with the first-time purchase of a second car, etc. One approach to test whether HVO increases for a given population of new car buyers is through simulation of the average car market. This is done in Ref. [16] for the Toyota Prius. Another approach, adopted in the present paper, is to compare with a representative control group. We will compare vehicle transaction behavior of Prius buyers with that of Corolla and Avensis buyers.

2.3. On the Toyota Corolla, Prius, and Avensis

The Toyota Prius is the first hybrid vehicle that reached a sales volume of over 100,000 units, and that is successful in all 3 major car markets, such as Japan, U.S., and Europe. It was first introduced in Japan in 1997, with a redesign of the batteries by the year 2000. In 2004, the second-generation, reworked Prius entered the market. Only the year 2004 version of the Prius, called Prius 2 among experts, is the topic of the

Table 1
Comparison of Toyota Corolla, Prius and Avensis (for Corolla and Avensis, numerous configurations can be ordered; we have selected the most sold engine configuration of the body type being most comparable to the Prius, which is available as 4-door liftback sedan only)

	Toyota Corolla Linea Sol	Toyota Prius	Toyota Avensis Linea Sol
Engine (fuel type)	1.6 VVT-i (gasoline)	1.5 VVT-i HSD (gasoline hybrid)	2.0 VVT-i (gasoline)
Body type, no. of doors	Hatchback sedan, 4 + 1 doors	Liftback sedan, 4 + 1 doors	Liftback sedan, 4 + 1 doors
Curb weight (kg)	1230	1375	1430
Length (m)	4.18	4.45	4.66
Rated power (kW)	81	57 + 50[a]	108
Acceleration time 0–100 km h^{-1} (s)	10.2[b]/11.8[c]	10.9[d]	9.1[b]/9.9[c]
CO_2 per km	168[b]/190[c]	104[d]	191[b]/221[c]
Recommended sales price including taxes[e]	EUR 18,440[b]/EUR 19,330[c]	EUR 24,140	EUR 24,000[b]/EUR 25,540[c]

[a] Short-term additional power from electric engine.
[b] Manual transmission, 5 gears.
[c] Automatic transmission, 4 gears.
[d] Continuously varying transmission (CVT).
[e] In Switzerland in September 2004 (time of Prius survey), applied CHF/EUR exchange rate 1.57 (data source: Toyota 2005).

present study. The Prius is available with hybrid powertrain only, no version exists that would be equipped with a conventional internal combustion engine only. As control group, we therefore, looked at buyers of the next-smaller Toyota car (Corolla) and next-larger (Avensis). Technical characteristics and sales prices of the Prius are listed in Table 1, together with figures on those configurations of Corolla and Avensis that can be best compared to the Prius. In Switzerland in 2004, the Prius 2 sold at about the same price as a Toyota Avensis (Table 1) and roughly EUR 4800 more as a comparable Toyota Corolla, which is sometimes regarded as being the conventional counterpart to the hybrid Prius 2 from a technical perspective [17]. It should be noted, however, that Prius and Corolla are distinct cars and do not correspond in all respects. We argue that on the automobile market, Prius is rather to be positioned between Corolla and Avensis, regarding curb weight, regarding vehicle length as surrogate for ''size'', and regarding acceleration time. It therefore, is hard to tell at what price a non-hybrid, conventional Prius would sell. In most automobile magazines, the Prius is classified as ''mid-size'' together with Avensis, whereas the Corolla is mostly referred to as ''lower mid-size'' (other names are ''compact class'' or ''B segment'').

2.4. On the Swiss car market

Switzerland belongs to the richest countries in the world, and among other sectors this affects the car market. Due to the high Swiss gross domestic product per capita, passenger cars bought in Switzerland are on average larger and have higher engine capacity. As shown in Fig. 1 (right-hand scale), the average new registered car in Switzerland has a higher rated power than in Western Europe, the difference roughly being a constant of 20 kW over the last 15 years. Also shown are the market statistics for those countries neighboring Switzerland (Germany, France, Italy, and Austria), whose population-weighted average is very similar to the whole of Western Europe. The engine capacity (Fig. 1, left-hand scale) reflects the same trend, with a difference of 300 ccm (slightly decreasing) between Switzerland and the rest of Europe. This can for the smaller part be explained by the lower fuel taxes (compared to Western Europe) and by the share of diesel-powered passenger cars (Fig. 2, right-hand scale). The Swiss diesel fleet is at a clearly lower level compared to the surrounding countries, due to the fact that diesel fuel did not benefit from a reduced tax level as in most European countries.

A sharp increase in the percentage of diesel passenger cars since 2000 can be identified, however, and is forecast to reach and level off at some 50% by the year 2020. The share of all-wheel driven cars (Fig. 2, left-hand scale) also is much higher (almost 20% compared to Western Europe with a steady increasing share that reached 7% in 2003), which is probably affected both by the wealth level and the presence of mountains.

Hence, the Swiss car market cannot be regarded as being representative for Europe, and therefore, it is not *a priori* clear whether our results may be generalized.

3. Surveys of new car buyers

Three separate surveys were performed. For each, the addresses of new car buyers were kindly made available by Toyota Switzerland. In September 2004, all Swiss buyers of the hybrid Toyota Prius 2 since its market entry in May

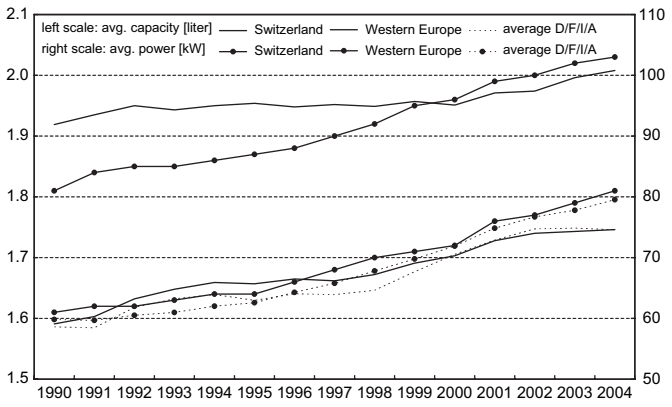

Fig. 1. Evolution of engine capacity (in liters; left scale) and power (kW; right scale) of new passenger car registrations in Switzerland, Western Europe, and Switzerland's neighboring countries D/F/I/A (weighted by car sales). Data source from Ref. [21].

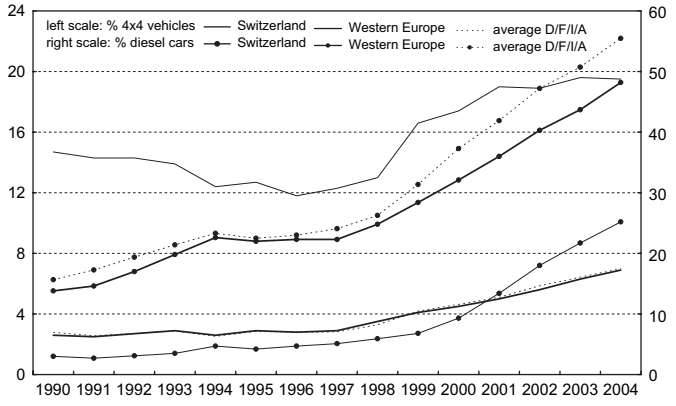

Fig. 2. Evolution of the market shares of 4-wheel driven (left scale) and diesel-powered (kW; right scale) new passenger car registrations in Switzerland, Western Europe, and Switzerland's neighboring countries D/F/I/A (weighted by car sales). Data source from Ref. [21].

2004 received a mail-out mail-back survey (for costs reasons, the Italian-speaking part of Switzerland was omitted from the survey). Questionnaires were not numbered or otherwise identifiable, and no reminder letters were sent out. Out of 367 questionnaires, 303 (82.56%) were returned.

In May 2005, 2 other surveys of 250 Toyota Corolla and 250 Toyota Avensis buyers were performed. Their postal addresses were randomly sampled from all buyers of the respective cars in the non-Italian speaking parts of Switzerland in 6 months before April 2005.

In the first 12–18 months after market entry in spring 2003, the waiting lists for the Prius were very long (often 9 months, sometimes reaching 12 months). This likely discouraged many potential buyers. We therefore have chosen to conduct the surveys on Corolla and Avensis buyers at a later time, in spring 2005, because the waiting time between order and delivery for the Prius in Switzerland was less pronounced in the period from October 2004 to April 2005 (3–4 months on average), and was less likely to discourage potential buyers.

For both Toyota Corolla and Avensis, the market average of builds, fuel types and gearbox types was presented in the survey: both hatchback and station wagon models, both gasoline and diesel engines, and both manual and automatic gearboxes. The monospace builds (marketed as Corolla Verso and Avensis Verso) were excluded, as they, in fact, are distinct car models. Note that the Toyota Prius is on the market only as a gasoline hybrid with hatchback and continuously variable transmission (CVT) (not to be confused with an automatic gearbox).

Toyota Corolla and Avensis have been selected because they are those non-hybrid vehicles on the market that are most similar to the Prius. It can be argued that a large percentage of Corolla and Avensis buyers could actually have opted for the Prius, as the following conditions are fulfilled: (i) need or willingness to purchase a new car; (ii) availability of the necessary funds in the order of magnitude of EUR 20,000–27,000; (iii) Toyota as acceptable brand; and (iv) looking for a mid-sized car.

The questionnaire consisted of 5 blocks with a total of 33 closed questions and 2 additional open questions of general scope. Item block A (7 questions) deals with the car purchased, whether an old vehicle had been disposed off (and if yes, what kind of car), and which other vehicles are owned by the household. Block B consists of 8 questions on car choice behavior and Block C has 5 knowledge questions on the Toyota Prius. Block D addresses the mobility behavior (7 questions on season ticket ownership for public transport, parking space availability, and commuting behavior). The remaining 7 questions of block E serve socio-demographic statistics. The complete questionnaire (in German or in French) may be obtained from the corresponding author upon request. The present paper deals with block A (Sections 2–5) and block C (Section 6) only. We will report our findings on motives and preferences of purchasers of hybrid cars (blocks B and D) elsewhere.

In block A, people were not only asked to report brand and model name, but also engine capacity (in liters), gear type (automatic or manual), fuel type (gasoline or diesel), and model year (vintage). These data allow for a precise identification of any vehicle in the Swiss database on vehicle type registrations and provide us with all technical characteristics including size, weight, and fuel consumption of the vehicle. There is also a redundancy such that missing data can often be filled in. For example, fuel type can in most cases be derived from engine capacity (and the other way round: imprecise engine capacity can be corrected for using fuel type), automatic gear often has not been sold for smaller engine sizes, etc.

The data quality of the returned questionnaires was unusually high and allowed for the precise identification of over 97% of all vehicles that were owned by the households prior to the purchase of the Prius 2. For the remaining 2.9% of vehicles, we assigned the most sold car type for the brand, model and vintage specified.

4. Analysis of car size evolution

For the 3 car types, 153, 303, and 130 questionnaires (for Corolla, Prius, and Avensis, respectively) were used for the present analysis. Table 2 lists averages of engine capacity, rated power, length and curb weight, alongside with fuel consumption (common figure used in Europe) and fuel efficiency (common in Northern America). We investigate whether car size increases more for hybrid car purchasers as compared to the control group of conventional Corolla and Avensis purchasers. As surrogate for "car size" we use both empty vehicle weight and empty vehicle length. Table 3 lists the differences between those cars having been replaced and the cars that have been replacing them. As can be seen, curb weight increased by 8.8 kg for Prius buyers. This is clearly below the before-mentioned market trend, and significantly lower than for the control group (54.4 kg, $P = 0.01$). Fig. 3 depicts the distribution of curb weight classes of those vehicles having been replaced. The chart shows that from this perspective, the Prius is closer to the Avensis.

The length of a vehicle in general shows a good correlation with car size segmentation. No significant increase in vehicle length could be observed (67 mm for Prius consumers, compared to 100 mm for the control group, $P = 0.256$). Fig. 4 depicts the distribution of vehicle length classes for the replaced cars. Here, Prius figures are in between of Corolla and Avensis.

Table 2
Average technical characteristics of the cars being replaced and the new cars having been bought

	Corolla buyers		Prius buyers		Avensis buyers	
	Replaced car	New Corolla	Replaced car	New Prius	Replaced car	New Avensis
Number	137	153	269	303	118	130
Engine capacity (ccm)	1672.3	1608.4	2021.7	1497.0	2010.0	2055.2
Rated power (kW)	64.7	86.8	100.1	57.0	96.5	106.1
Length (mm)	4216	4220	4383	4450	4451	4666
Curb weight (kg)	1194.0	1231.3	1366.2	1375.0	1353.3	1430.3
CO_2 (g/km)	187.0	177.4	203.7	104.0	206.1	203.3
Fuel consumption (litre/100 km)	7.82	7.39	8.47	4.30	8.62	8.42
Fuel efficiency (U.S. mile per U.S. gallon)	30.3	32.0	27.9	55.0	27.4	28.1
Model year/vintage[a]	1995.5	2005.0	1996.7	2004.0	1997.4	2005.0
Annual mileage (km/a)[b]	13,981		15,704		19,350	
Fuel type						
Gasoline (%)	98	96	94	100	96	86
Diesel (%)	2	4	6		4	14
Gear type						
Manual (%)	82	70	50		63	39
Automatic (%)	18	30	42		37	61
Gearless transmission (%)	0	0	8	100	0	0
Car shape						
Station wagon (%)	36	17	20		19	57
Limousine/hatchback (%)	64	83	76	100	79	43
Cabrio (%)	0	0	4		2	0

[a] Model year based on 257 (Prius), 133 (Corolla), and 116 (Avensis) vehicles.
[b] Annual mileage based on 263 (Prius), 135 (Corolla), and 116 (Avensis) vehicles.

Hence, in summary, we conclude that no increase in car size for hybrid car purchasers can be observed, on the contrary, there are some indications that increase in car weight and length are below-average for Toyota Prius buyers.

On average, the vehicles being replaced by hybrid Prius had a CO_2 emission level of 203.7 g km^{-1}, compared to 104 g km^{-1} for the Prius. On average for new registrations in Switzerland, CO_2 emissions dropped from 214.9 in the year 1996 to 191.9 g km^{-1} in the year 2004 (test cycle: NEDC) [18]. This corresponds to a decrease of 2.875 g km^{-1} per year.

It should be noted that for Corolla buyers, CO_2 emissions dropped from 187 to 177.4 g km^{-1}, where the cars were being replaced on average age of 9.5 years. This means that CO_2 emissions of the new Corolla cars are higher than expected. The same holds true for Avensis cars, the predecessors of which were 7.6 years of age, but have been replaced by new Avensis cars with a rated CO_2 emission level that is only 2.8 g km^{-1} lower, whereas the market average dropped by 22 g km^{-1} over the time frame of 7.6 years. These differences arise from the fact that most individuals increase car size with each purchase, which, however, does not show up in the market average as young consumers fade in and old consumers fade out. So in order to assess possible above-average increases in car size for hybrid car purchases, one should make use of control groups of conventional new car buyers. Comparing the increase in car size with market trend data, as done for example by the authors in Ref. [16], in fact is too strict: it is a sufficient but not a necessary proof of absence of a rebound effect.

Table 3
Mean differences in technical characteristics between replaced and new cars

Difference between new and replaced vehicle[a]	Control group				
	Corolla	Avensis	Joined	Prius	P[b]
Number of cases	137	118	255	269	
Engine capacity (ccm)	−63.9	+45.3	−15.0	−524.7	0.000**
Rated power (kW)	+22.2	+9.6	+16.4	−43.1	0.000**
Length (mm)	+4	+215	+100	+67	0.256
Curb weight (kg)	+37.3	+77.0	+54.4	+8.8	0.010**
CO_2 (g/km)	−9.6	−2.8	−6.3	−99.7	0.000**
Fuel consumption (lit./100 km)	−0.43	−0.20	−0.32	−4.17	0.000**
Fuel efficiency (U.S. mile per U.S. gallon)	+1.7	+0.7	+1.2	+27.1	0.000**
Car age at time of replacement	9.5	7.6	8.6	7.3	0.467

[a] Only respondents considered that actually replaced a previously owned vehicle.
[b] 2-Sided T test assuming not-equal variances (**significance 1% level, *significance 5% level).

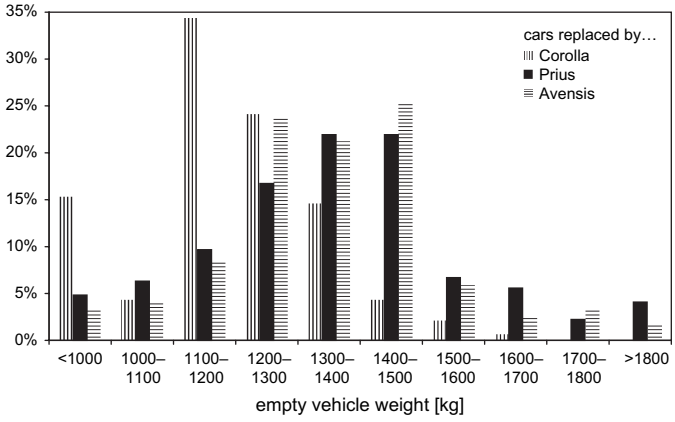

Fig. 3. Empty vehicle weight distribution of previously owned vehicles having been replaced by Corolla, Prius, and Avensis buyers.

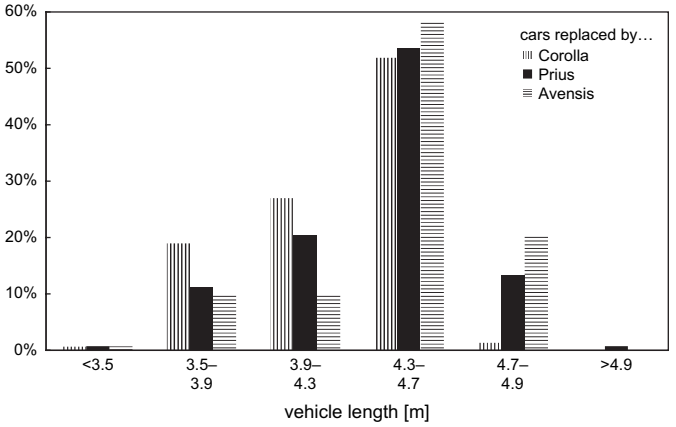

Fig. 4. Vehicle length (in millimeter) distribution of previously owned vehicles having been replaced by Corolla, Prius, and Avensis buyers.

5. Analysis of household vehicle ownership evolution

In this section we investigate whether the vehicle transaction behavior of hybrid car purchasers does lead to an above-average increase in average HVO, i.e., in the number of cars per household on average. We again compare hybrid Prius buyers with conventional Corolla and Avensis buyers.

As discussed in the preceding section, the viewpoint of the individual is distinct from the market average. Whereas the individual consumer will, on average, increase the number of vehicles owned up to the age of, say, 40–50 years, and will then decrease again, this individual pattern will not show up in the market average, as consumers fading in and consumers fading out of the market will cancel each other out.

For the vehicles having been replaced (technical characteristics of which are listed in Table 2), Table 4 lists the vehicle transaction behavior. We distinguish 3 types of vehicle transactions:

- Replacement purchase: an old vehicle is disposed off; the vehicle stock remains constant;
- First-time purchase: the household did not previously own a vehicle;
- Stock increase purchase: the household already owned one or more cars, of which none is disposed off, so the vehicle stock increases by 1 vehicle.

As can be seen, the percentage of so-called replacement purchases is similar for all groups, with the Prius percentage of 90.0% being between Corolla and Avensis percentages (89.5% and 90.8%, respectively; $P = 0.955$ for a two-sided Student's t-test assuming non-equal variances). A difference between hybrid and conventional cars can be found, however, for the percentage of first-time purchases (only 3.3% for the Prius, but 7.2% for Corolla and 6.2% for Avensis; statistically not significant with $P = 0.062$). Correspondingly, the number of cases where no vehicle has been disposed off is 3.3% for Corolla and 3.1% for Avensis, but 6.7% for Prius ($P = 0.050$). This is not a proof of increasing HVO for the following reason: the Toyota Prius was very successful that the waiting time between order and actual delivery of the car was up to 12 months for orders taken in the first 9 months after market entry. This of course made it impossible to purchase a Prius for those potential buyers who were in urgent need of a car. This fact, in our opinion, probably accounts in full for the difference in vehicle purchase behavior. This is also illustrated by the Swiss market average of the percentage of new car purchases that do not immediately replace a previously owned vehicle, which is 20% [16], i.e., much higher than the corresponding figures for either the Corolla, Prius or Avensis buyers (Table 4). There is a significant difference in average HVO after purchase (1.65 for hybrid buyers, 1.43 for the control group, $P = 0.001$). This can be related to higher income and education levels for hybrid buyers [22].

6. Effect of car ownership tax reductions

In Switzerland, annual car ownership tax is regulated not at the federal level, but by the 26 cantons separately. Both tax

Table 4
Statistics on household vehicle ownership after the purchase of new Corolla, Prius, or Avensis car (#hh = number of households)

Replacement	# cars after purchase	Control group								P [b]
		Corolla buyers		Avensis buyers		Joined		Prius buyers [a]		
		# hh	%	# hh	%	# hh	%	# hh	%	
Disposal of previously owned vehicle	1	92	89.5	69	90.8	161	90.1	146	89.3	0.955
	2	38		40		78		96		
	3	4		9		13		18		
	4	2		0		2		6		
	5	1		0		1		1		
First-time purchase (no prev. veh.)	1	11	7.2	8	6.2	19	6.7	9	3.0	0.064
No vehicle disposed	2	5	3.3	4	3.1	9	3.2	15	7.7	0.050
	3	0		0		0		4		
	4	0		0		0		3		
	5	0		0		0		1		
Sum		153	100	130	100	283	100	299	100	

[a] For this table, 4 commercial fleet owners of Prius with over 30 vehicles each have been excluded.
[b] 2-sided T test assuming non-equal variances.

level and tax base (either curb weight, engine capacity, rated power, emission level, curb weight + maximum payload, or a combination thereof) vary among the cantons. In September 2003, 6 cantons had introduced tax reductions for environmentally friendly cars so that the Toyota Prius could benefit from them: Geneva and Basel-Land have a tax rebate of 100% (limited to 3 years in Geneva). Lucerne offers an annual reduction of EUR 30. Zurich and Basel-Stadt have reductions of 50% and 10%, respectively. The canton of Ticino goes beyond the other cantons by offering a cash reward for the purchase of highly fuel-efficient (or electric) vehicles, and offers EUR 1330 in the case of the Toyota Prius.

Block C of our questionnaire also asked, in the case of Prius buyers only, in which canton the Prius buyer lives, and whether he or she benefits from a car ownership tax rebate. This allows us to give a rough, tentative estimate whether such tax rebates are an effective and efficient policy measure. As our questionnaire was not sent to the Italian-speaking canton of Ticino, this analysis accounts for 5 out of the 6 cantons listed above.

Out of 296 questionnaires with valid answers (7 questionnaires had missing values on the canton), 120 (40.5%) lived in one of the 5 cantons with a tax rebate of some kind. The population share of these 5 cantons with respect to the whole of Switzerland without Ticino is 35.2%. All Corolla and Avensis (34.6%) from our control group were sold to these cantons. This amounts to a Prius purchase density of 0.0484 per inhabitant for cantons with tax rebate, and 0.0385 for cantons without such a rebate. In other words, these tax rebates seem to be associated with a Prius sales level that is 25.7% higher. We tested this result for statistical significance using bootstrap resampling methods as proposed in Ref. [19]. The two-sided 95% confidence interval for the ratio of Prius buyers living in cantons with tax rebates, 40.5%, is [36.49%, 44.59%], which does not include the Swiss average of 35.2%. Computing the odds ratio (again based on a two-sided bootstrap estimate using 100,000 samples) leads to a similar result: the 95% confidence interval for the odds ratio, 1.2582, is [1.0223, 1.5163] and hence does not include unity.

Assuming an average duration of the tax rebate of 4 years (the canton of Geneva explicitly limits to 3 years), the average tax loss for the government is about EUR 426 in total per Prius purchased (population-weighted average for the 5 cantons). To compute the efficiency of these tax rebates, we have to realize that only 1 out of 5 Prius cars (corresponding to sales increase of +25%) would not have been purchased had the tax rebate not been present. A total tax loss of EUR 1658 is associated with a net effect of 1 additional Prius in the market.

The market average in Switzerland of new gasoline car registrations in 2004 corresponded to 196 g CO_2 per km. Compared to this market average, the Prius with a CO_2 emission level of 104 g km^{-1} will save 14.7 tons CO_2 over 160,000 km (Swiss average vehicle lifetime).

Summarizing the above, rebates on car ownership taxes seem to be effective, i.e., in our case an increased sales level of Prius cars of 25% results. Their efficiency can be estimated at costs of EUR 1658 for 14.7 tons CO_2, i.e., abatement costs of roughly EUR 107 per ton CO_2. This figure is tentative only, as it might be argued that it is an underestimation but also that it is an overestimation. Since tax rebates also lead to additional indirect effects (increased awareness for fuel efficiency in the public debate, etc.) that are not included in the above estimation of cost efficiency, the actual figure could be lower. On the other hand, it can be assumed that cantons which have a higher share of urban population, i.e., with above-average education levels, are also more likely to adopt hybrid-friendly tax rebates. Hence part of the higher sales numbers in cantons with tax rebates might be attributable to the general environmental values of the population and not be causally related to the tax rebate itself, so the actual figure could be higher than estimated above.

7. Discussion, conclusions, and outlook

The goals of our research were to investigate the possible presence of 2 rebound effects possibly associated with hybrid cars: people could tend to upgrade from small or already fuel-efficient vehicles to the hybrid car, or households could tend to increase the number of cars owned. We conducted a survey with all Swiss buyers of the hybrid Toyota Prius 2 since its market entry in 2004 (303 out of 367 questionnaires were returned), and, as control group, surveys with 250 Toyota Corolla and 250 Toyota Avensis new car buyers, randomly sampled (153 Corolla and 130 Avensis questionnaires were returned). Official registration data (including fuel consumption, size and empty vehicle weight) were matched to the replaced vehicles owned by the surveyed households prior to the purchase of the new car.

Our results show that neither the first nor the second rebound effect investigated could be detected. Increase in vehicle length even was somewhat lower for hybrid buyers compared to the control group ($P = 0.256$, not significant). Increase in vehicle curb weight was clearly lower for hybrid buyers ($P = 0.010$). We conclude that hybrid car buyers on average do not switch from small, already fuel-efficient cars to the new hybrid car.

Regarding vehicle ownership, the percentage of vehicle purchases where no previously owned vehicle had been disposed off, i.e., where the vehicle stock increased due to the purchase of the new car, was twice as high for hybrid cars in comparison to our control groups with conventional cars ($P = 0.050$). We explain this with the extraordinary long waiting time of up to 12 months for the Prius, which caused a preselection of potential buyers toward multi-car households. Hence we conclude that the hybrid Prius was not associated with an increase in average HVO, confirming the findings of Ref. [16] while applying another method (survey of control group of conventional car buyers, vehicle ownership simulation model). Hybrid cars more often enter multiple-car households (1.65 cars after purchase for hybrid buyers, control group 1.43, $P = 0.001$), which can be explained by higher income and education levels of hybrid buyers [22].

We also analyzed the effect of car ownership tax rebates. It could be shown that such tax rebates indeed do influence the

number of sales of hybrid vehicles. A rough estimate of the efficiency of such tax rebates indicates that abatement costs are in the order of magnitude of roughly EUR 107 per ton CO_2. This might seem rather high compared to carbon reduction measures in other economic sectors, but is competitive when compared to CO_2 abatement policies focusing on road transport.

Overall, we conclude that hybrid cars indeed are suited to play a role, during the next 5 years, in energy policy schemes aiming at reducing CO_2 emissions from individual road transport. Their very low fuel consumption does not motivate people to switch to larger cars or to buy additional cars. Hence hybrid vehicles are not only fuel-efficient on a per-vehicle basis, but constitute a technology effective in lowering overall CO_2 emissions. And the introduction of tax rebates for hybrid vehicles seems to be effective (significant higher sales numbers in Swiss cantons having tax rebates), and also to be efficient, with abatement costs per ton CO_2 comparable to other carbon reduction measures in the road transport field.

In the near future, new cars equipped with hybrid technology will come to market in Europe. We intend to conduct analogous surveys for other hybrid cars, namely Honda Civic IMA and Lexus RX400h. Especially the latter will be of interest with regard to the postulated existence of rebound effects due to reduced socio-psychological (rather than financial) cost-of-ownership.

Also, we plan to ask the Honda Civic and Lexus RX buyers (both hybrid and conventional powertrains) again, some 12 months after purchase, how many miles they have driven the new car. This would allow for the investigation of the third possible rebound effect, increase of vehicle kilometers driven annually due to the fact that lower fuel consumption leads to cheaper operation cost. Ref. [20] hypothesizes that this rebound effect should in fact be present.

Acknowledgements

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Curriculum Vitae

Anja Peters was born in Erkelenz, Germany on June 12, 1978. From 1997 to 2003 she studied Psychology at the University of Trier, Germany. Her diploma thesis on 'Umweltschutz am Arbeitsplatz - Eine qualitative Interviewstudie zur Ableitung von Interventionsmöglichkeiten zur Förderung umweltschonenden Mitarbeiterverhaltens in einem Großunternehmen der Automobilbranche' was completed in 2003.

From October 2004 till November 2008 Anja Peters was employed as a research assistant at the Institute of Environmental Decision (IED), Chair of Natural and Social Science Interface (NSSI). She was involved in several research projects, most notably in 'Entscheidungsfaktoren beim Kauf effizienter Neuwagen' ('Psychological variables influencing the purchase of fuel-efficent vehicles'), and in 'Lenkungsabgaben zur Senkung des CO_2-Ausstosses beim Neuwagenkauf. Hintergrund, Mechanismen, Prognosen.' ('Incentive schemes to reduce CO_2 emissions of new cars.') funded by the Swiss Federal Office of Energy. Her PhD thesis on 'How do people buy fuel-efficient cars?' was supervised by Prof. Dr. Roland W. Scholz and Prof. Dr. Heinz Gutscher.

Since February 2009 she has been employed as a senior researcher by the Fraunhofer Institute for Systems and Innovation Research (ISI). She is interested in ways of promoting sustainable consumption.